



PHAST
PHYSIQUE
ET ASTROPHYSIQUE
UNIVERSITÉ DE LYON

**ÉCOLE
DOCTORALE**
— 52 —

Supernovae standardisation with the ZTF volume limited DR2 Cosmo sample

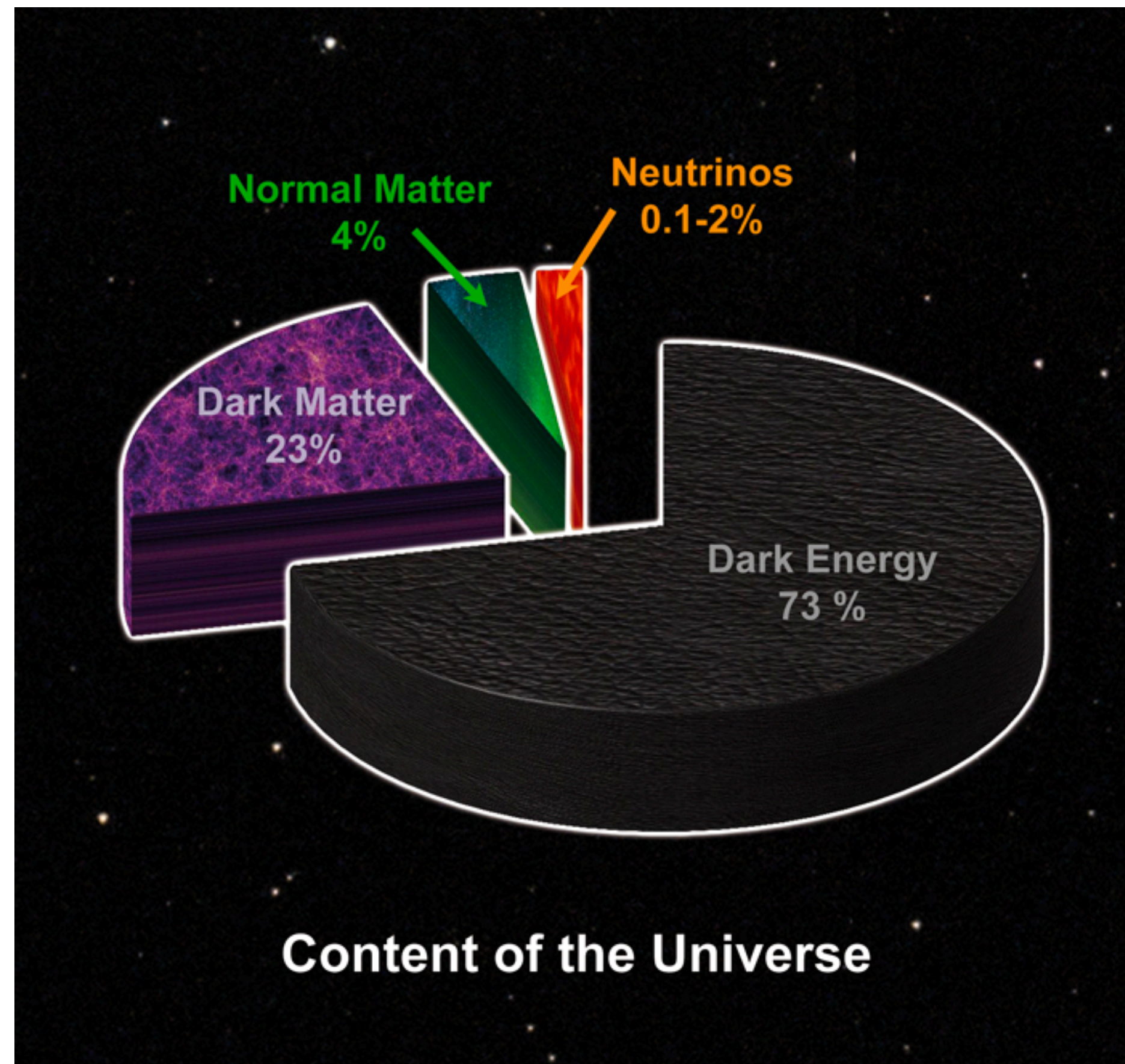
Supervisor: Mickaël Rigault

Madeleine GINOLIN - August 2023



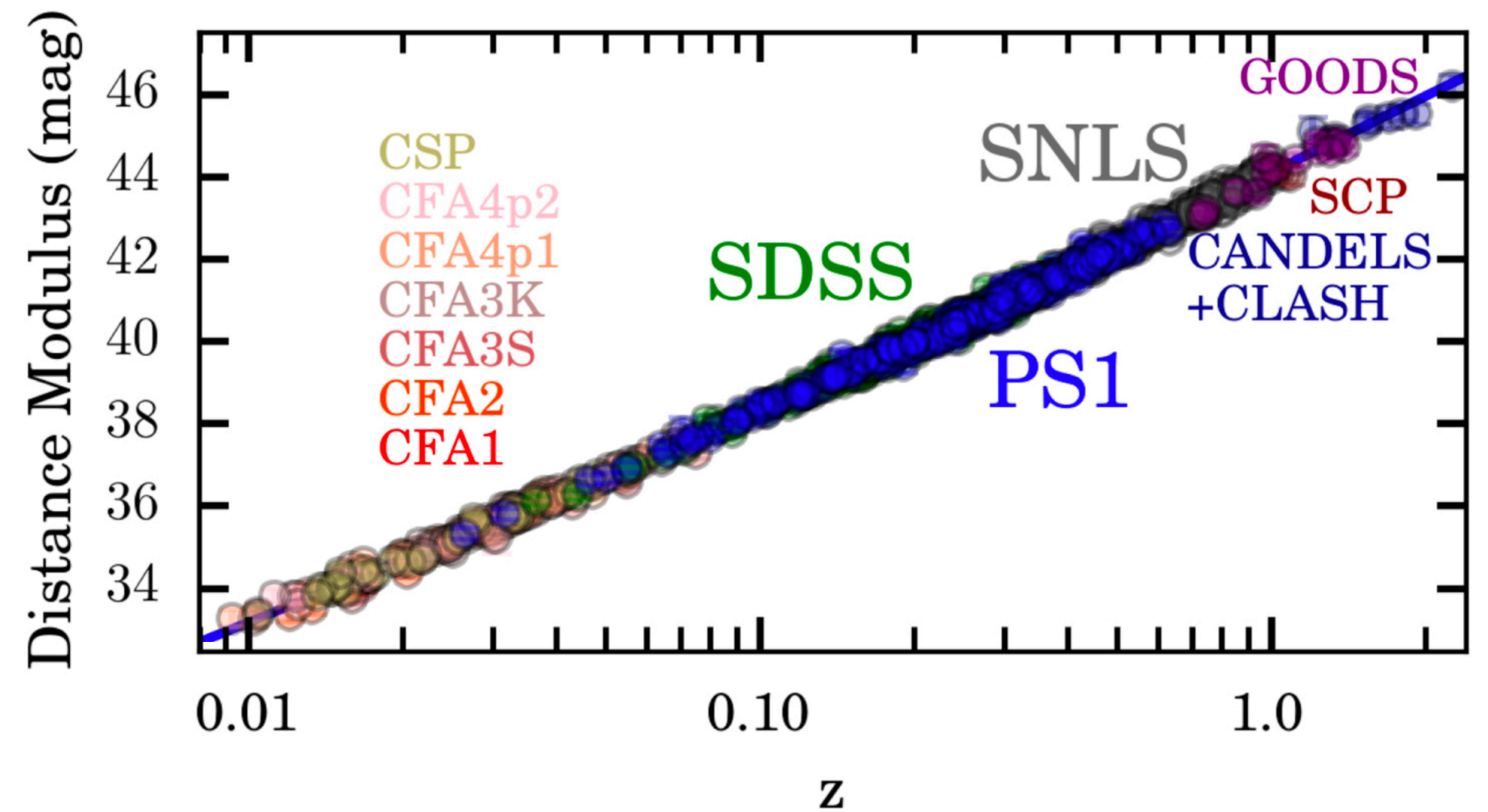
Cosmology

Λ CDM model



Credits: HAP / A. Chantelauze

$$v = H_0 D = cz$$

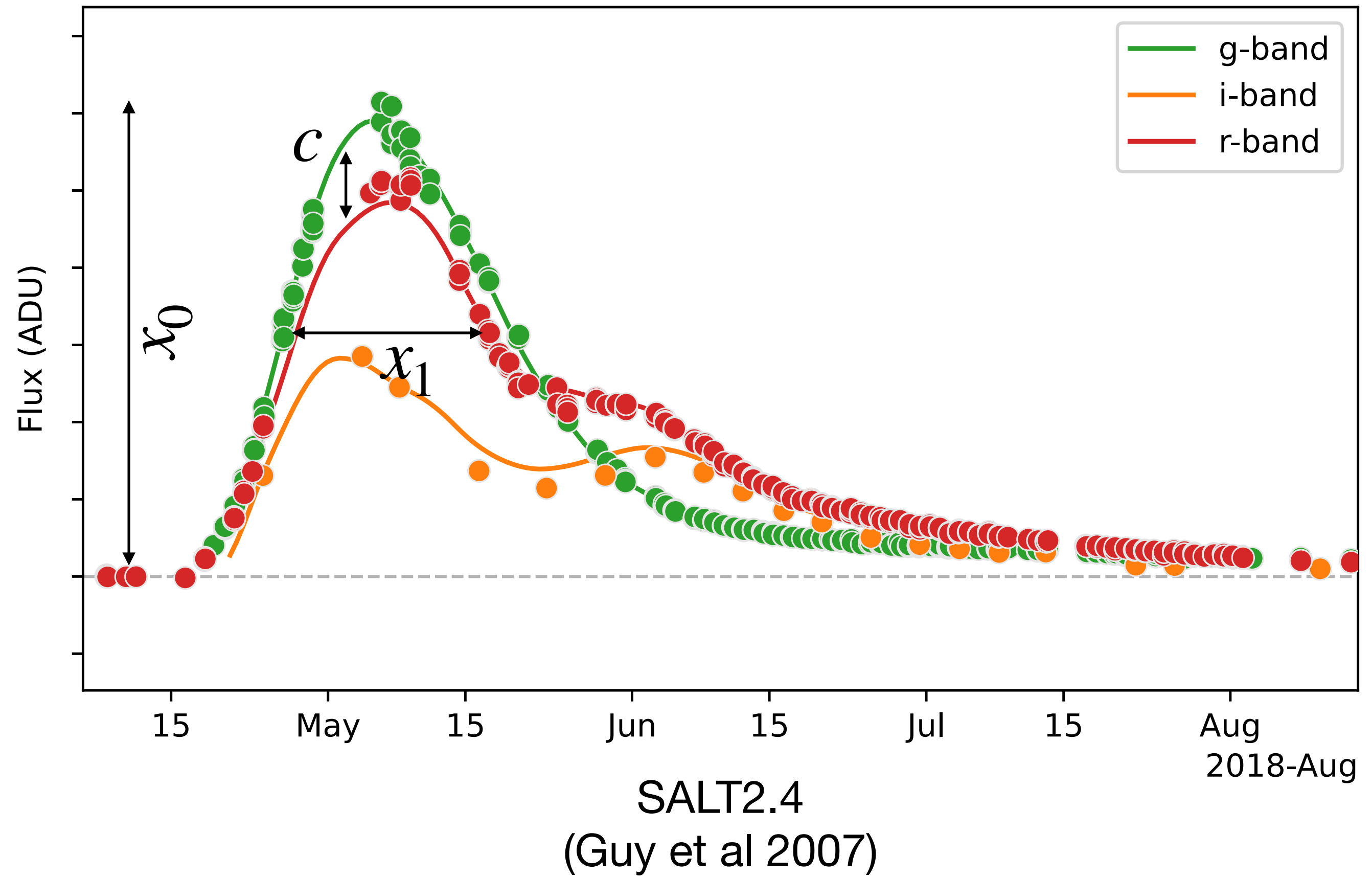


Scolnic et al (2018)

Supernovae

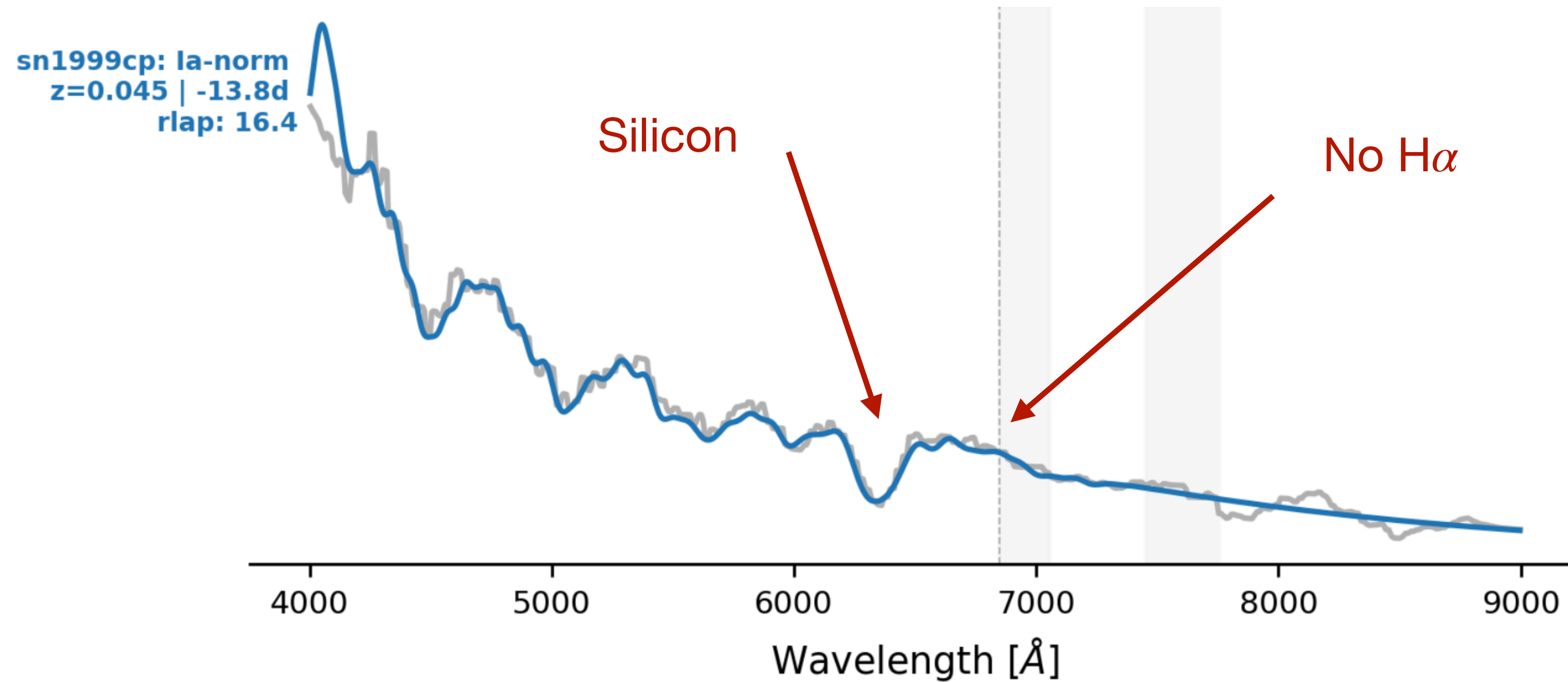


Credits: B.J. Fulton/
LCOGT/Caltech



x_0
 x_1
 c

Type Ia Supernovae

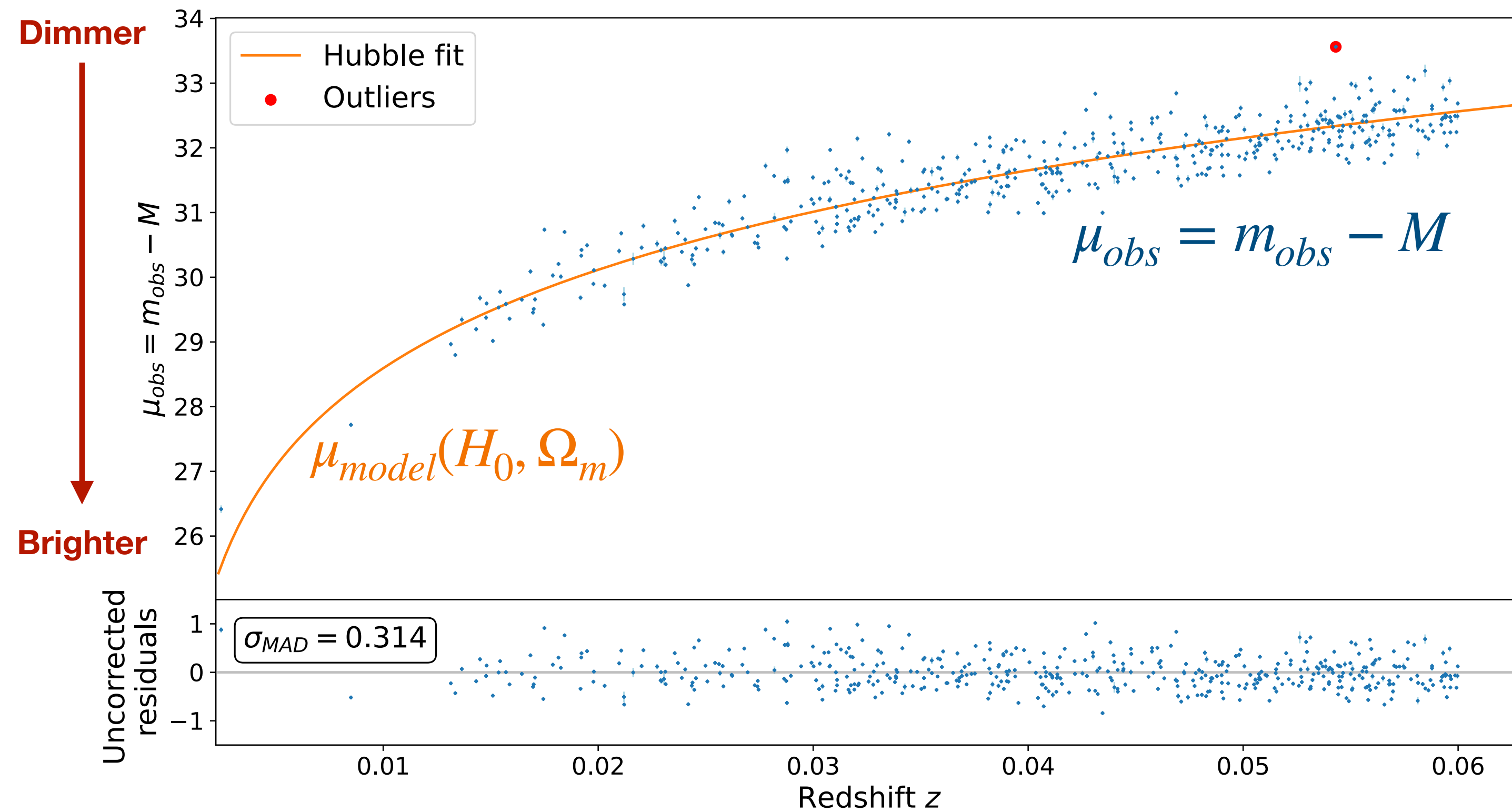


Typing

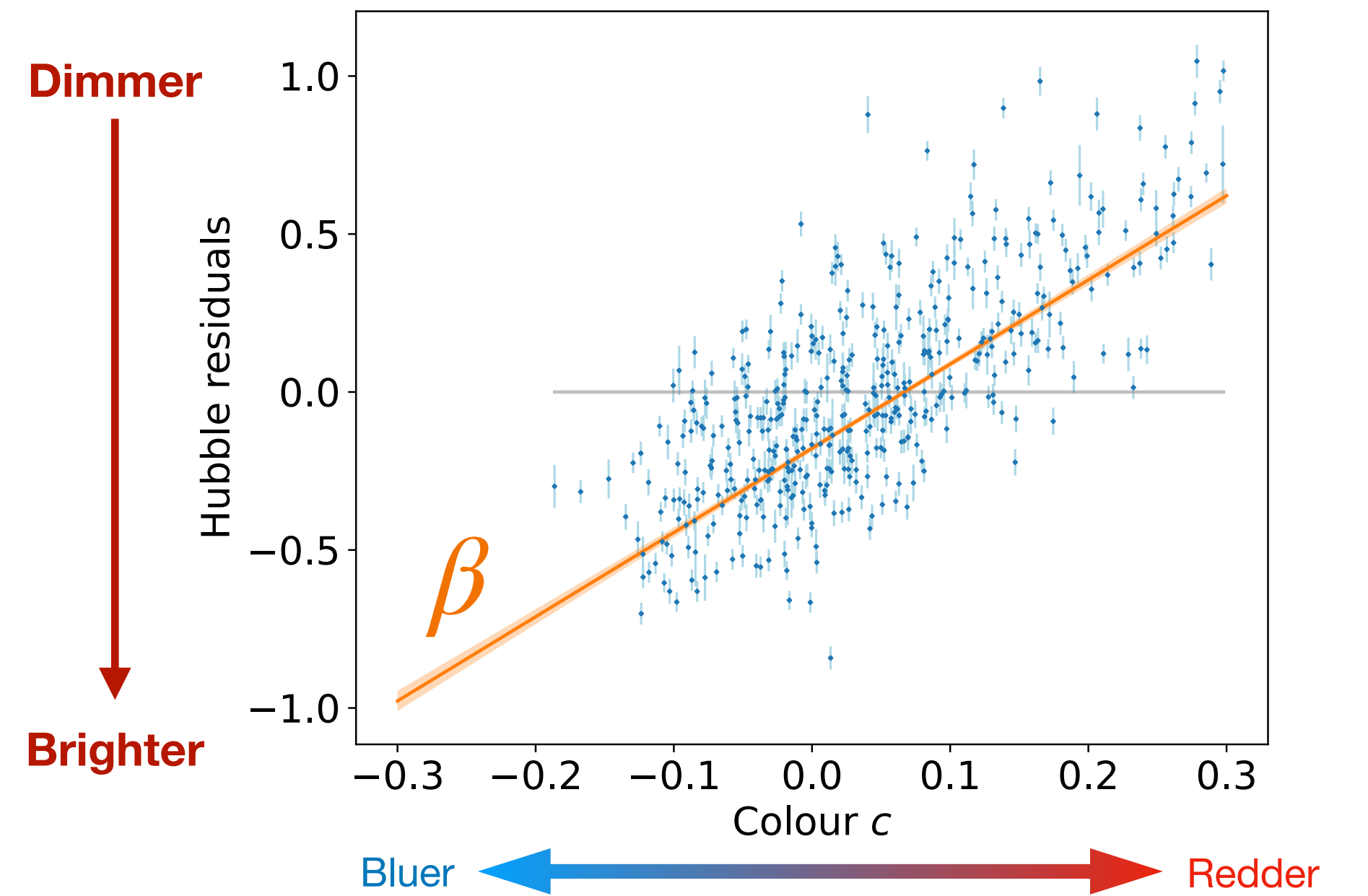
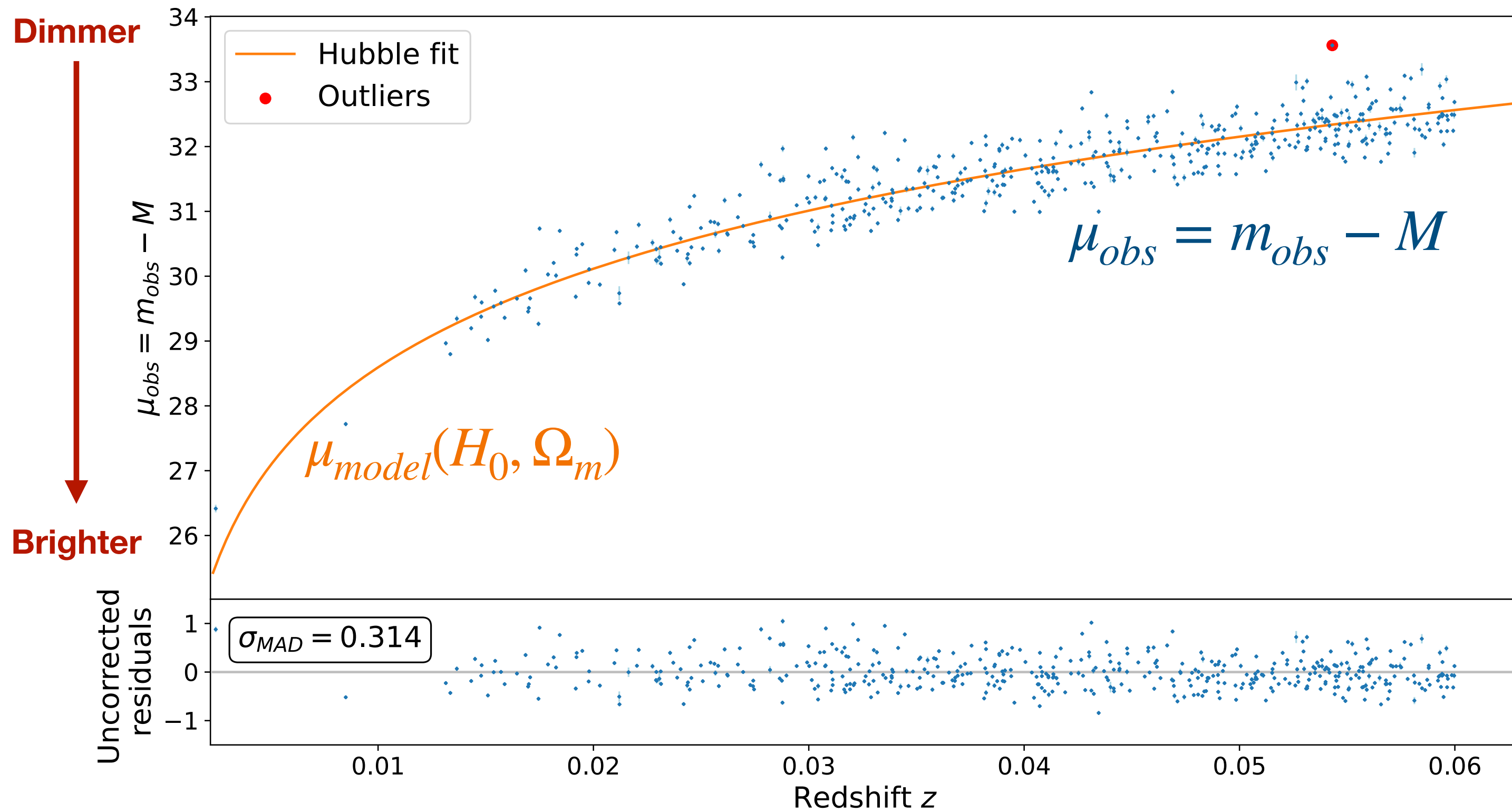
z

SNID
(Blondin & Tonry 2007)

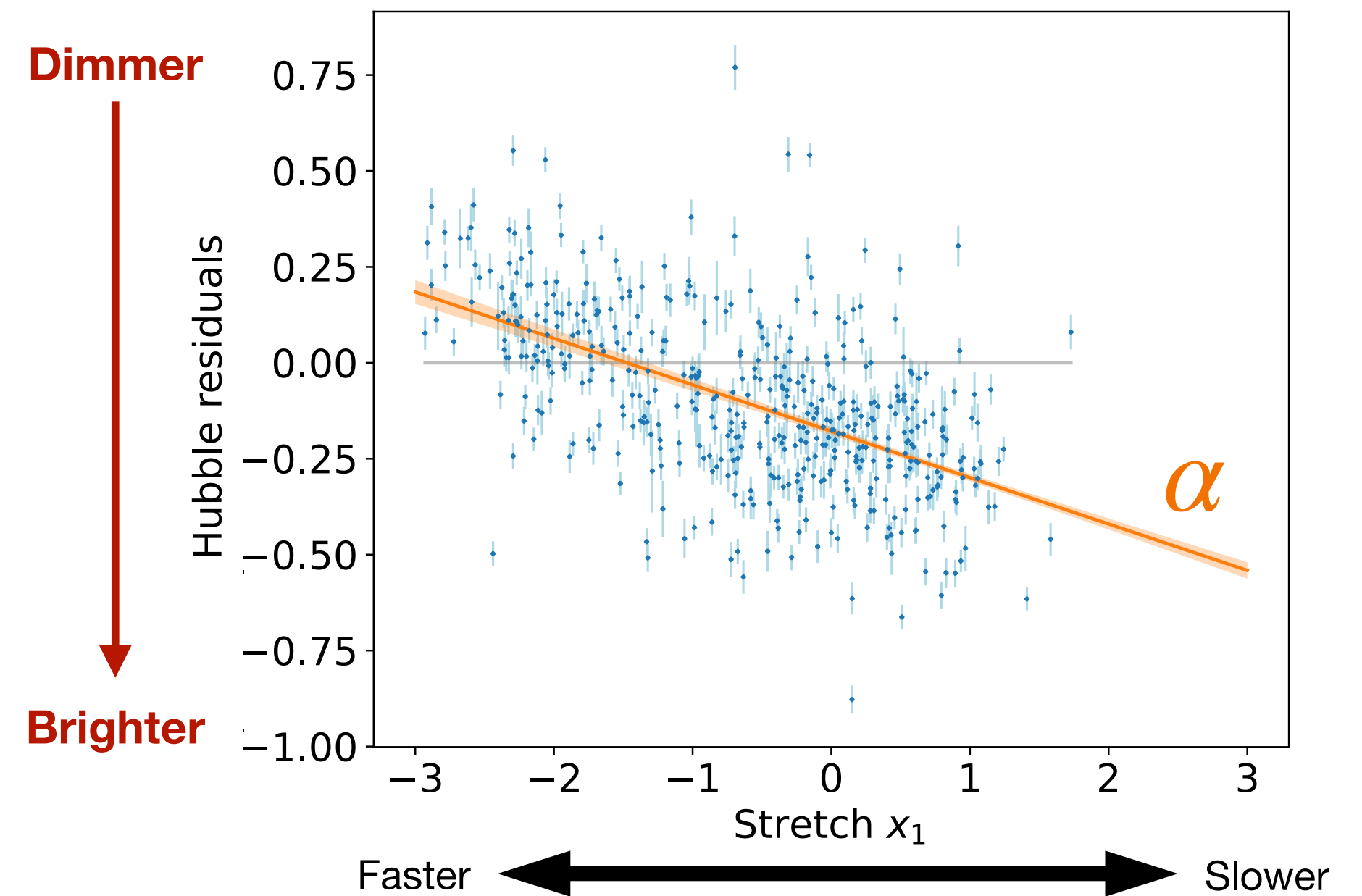
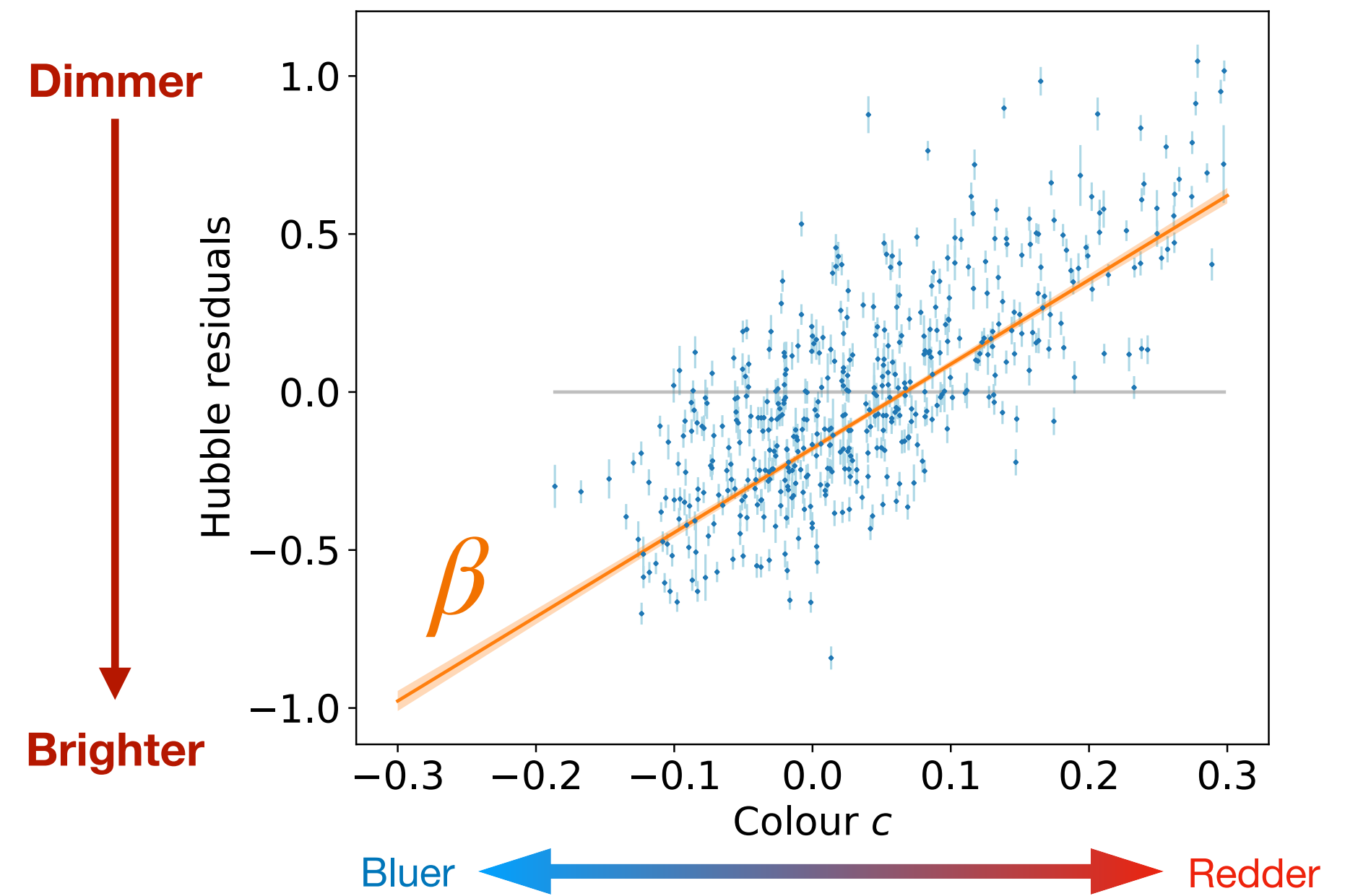
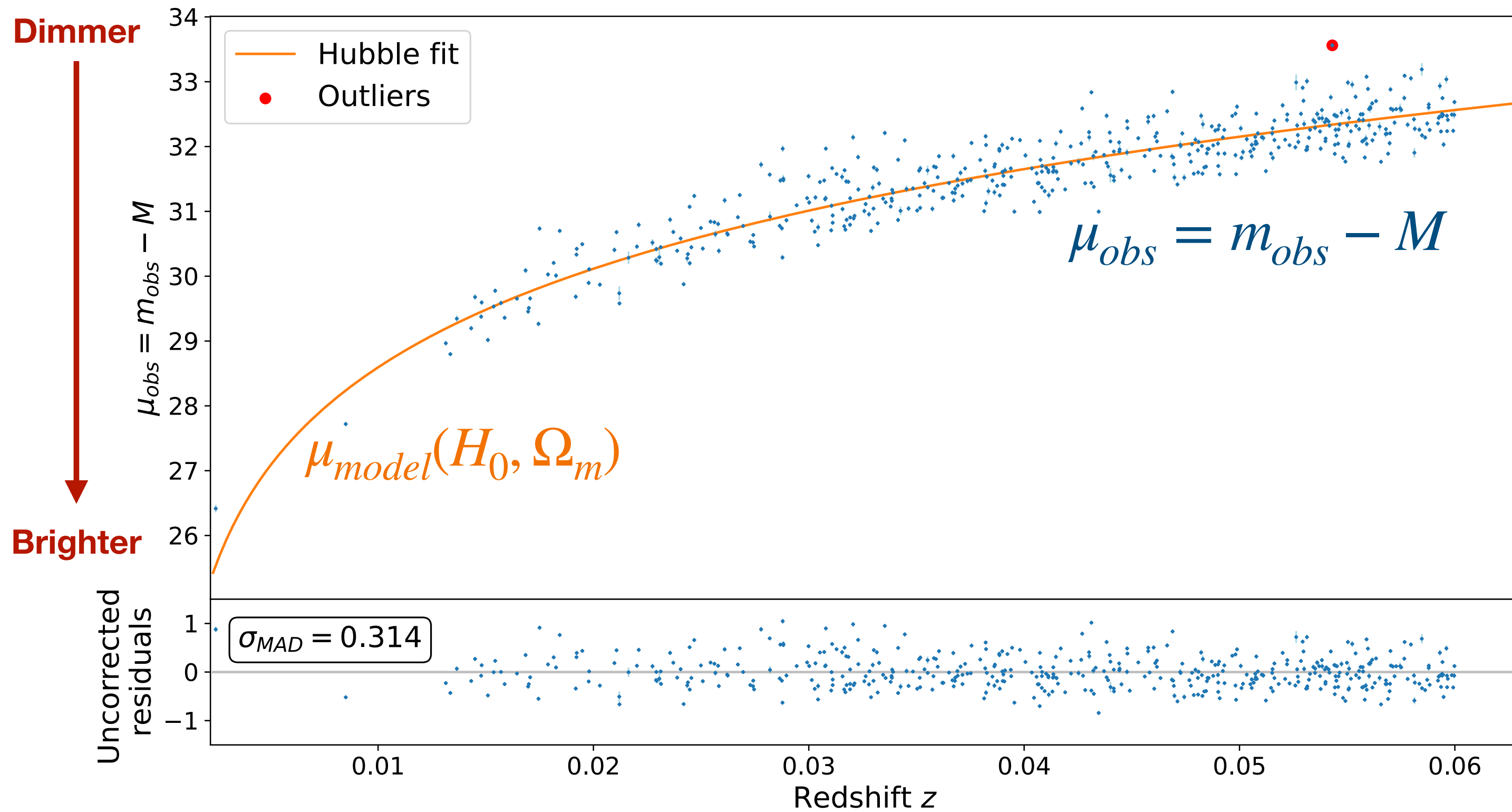
Cosmology with SNe



Cosmology with SNe



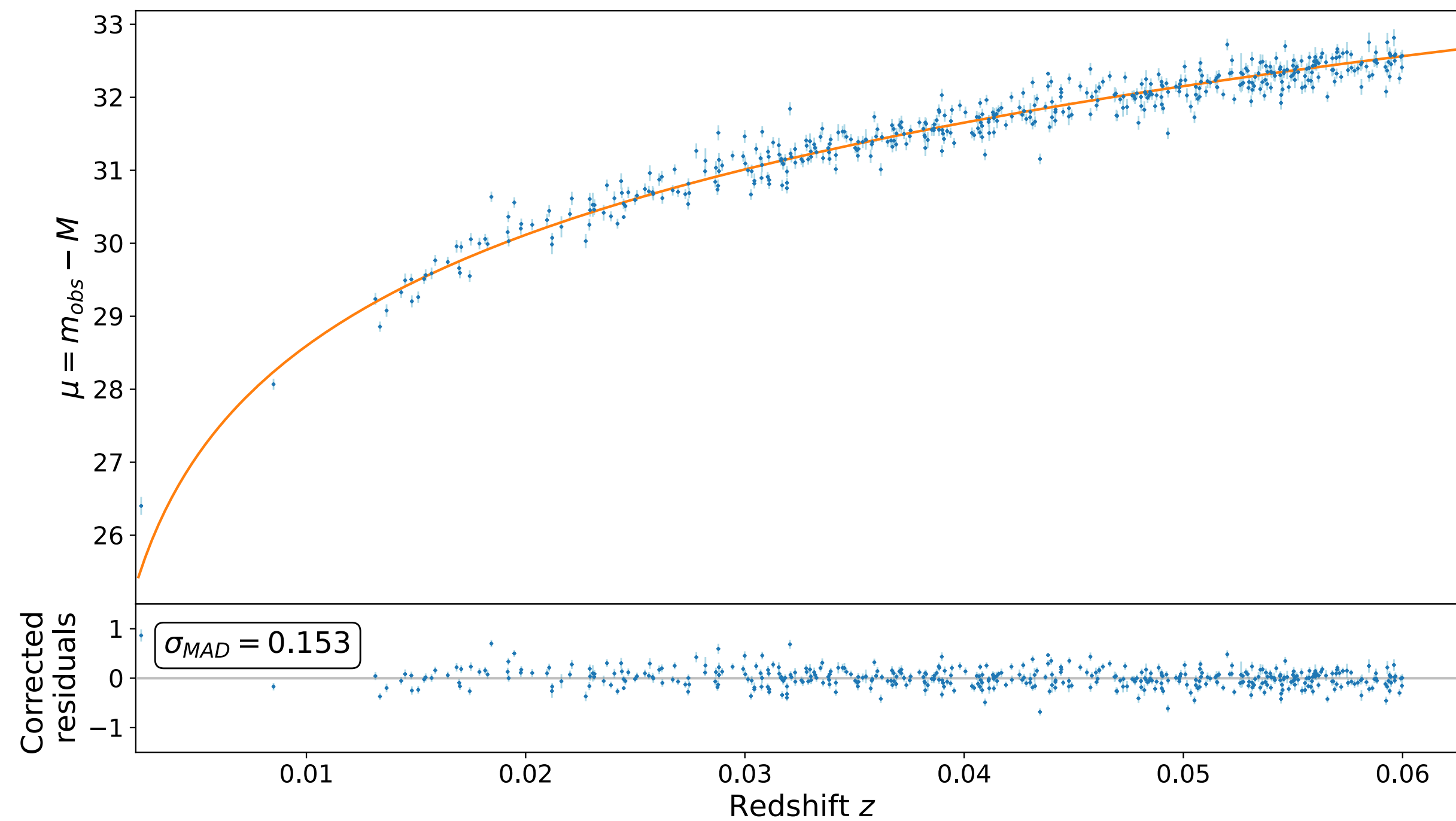
Cosmology with SNe



Cosmology with SNe

$$\mu + M = m_{obs} - \beta c + \alpha x_1$$

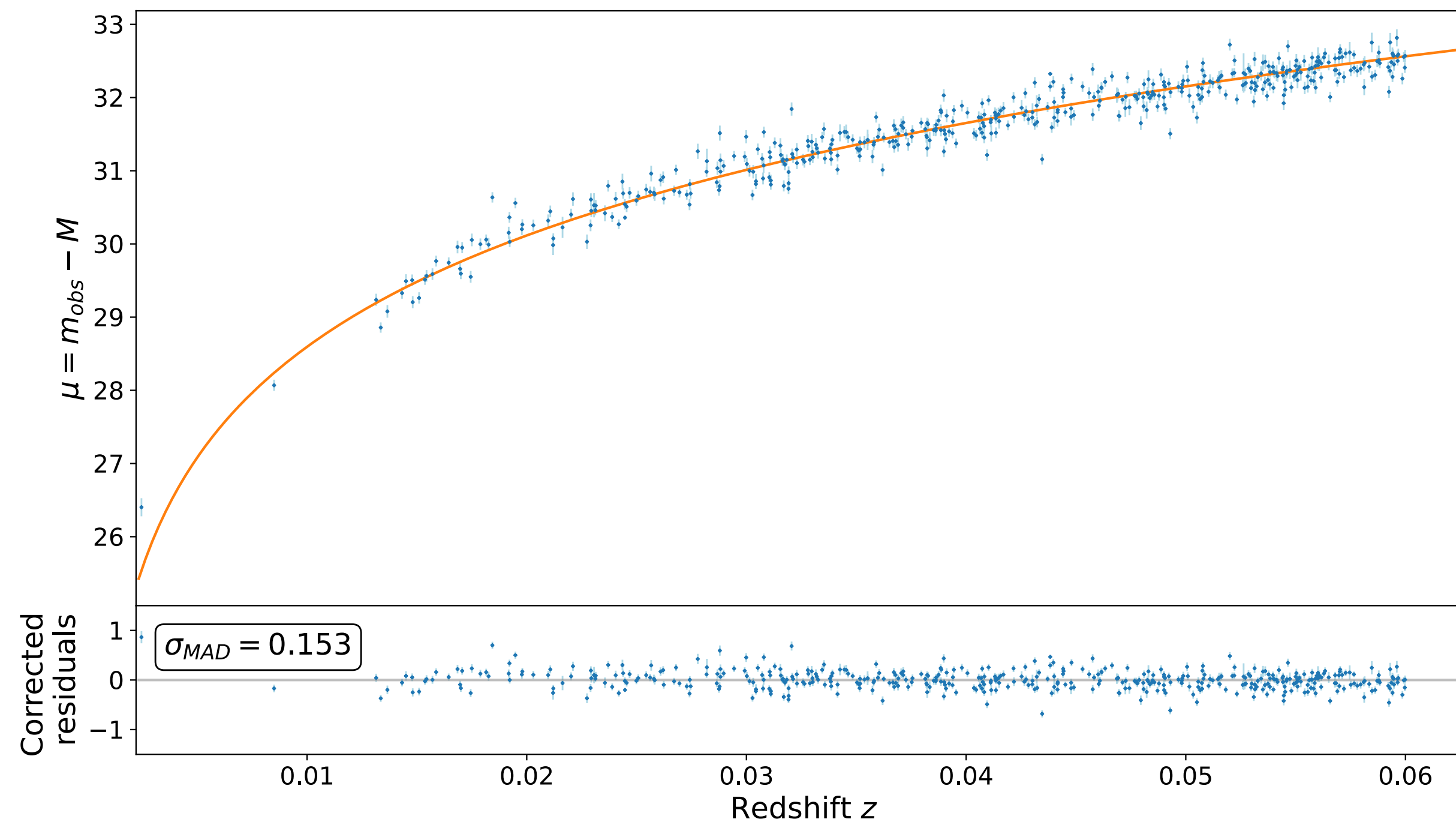
(Tripp 1998)



Cosmology with SNe

$$\mu + M = m_{obs} - \beta c + \alpha x_1$$

(Tripp 1998)

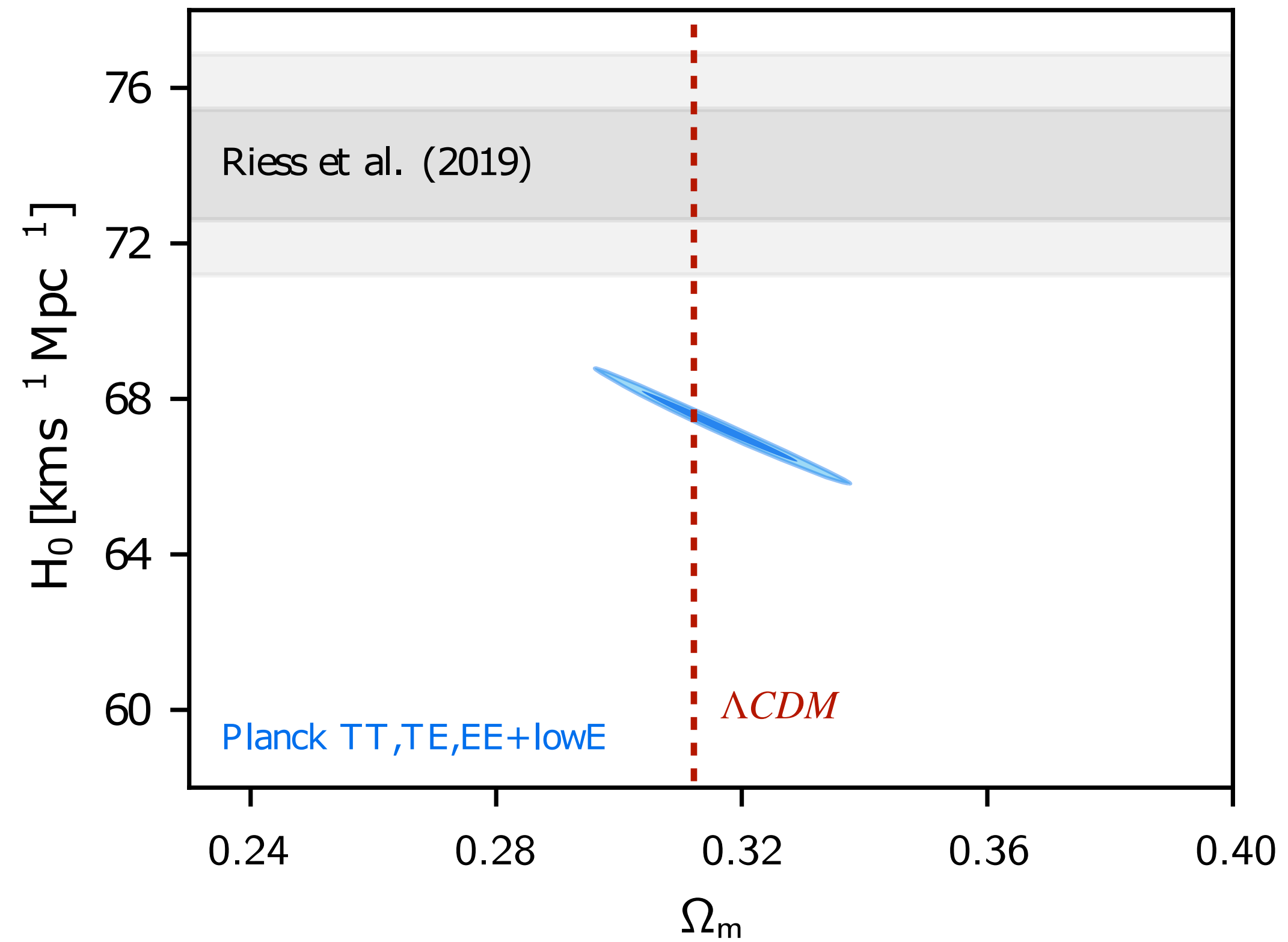


+

Anchoring to the Cepheids

$$\mu + M = m_{obs} - \beta c + \alpha x_1$$

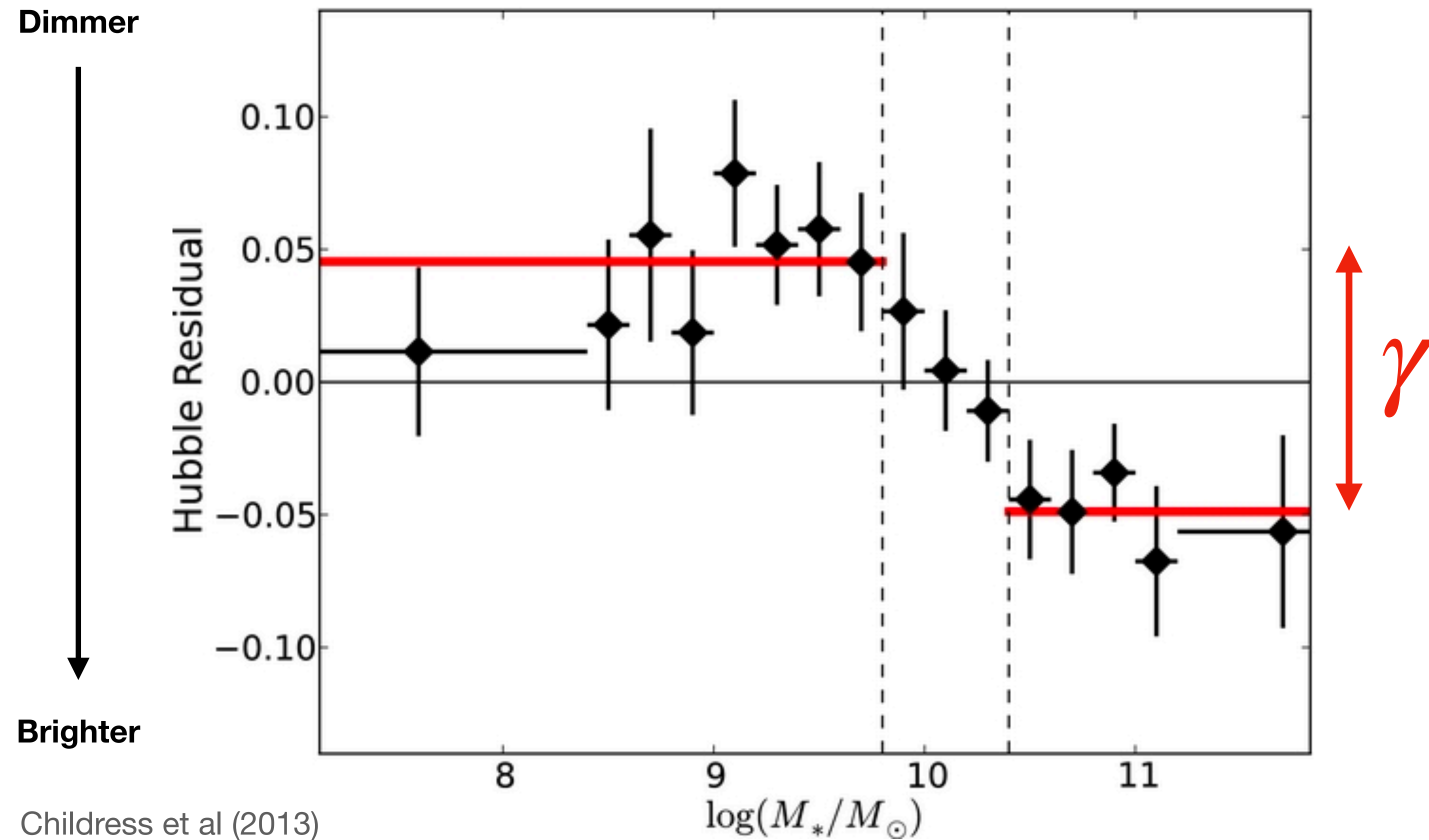
Hubble tension



Adapted from Planck collaboration (2020)

Astrophysical biases

Mass step γ



Childress et al (2013)

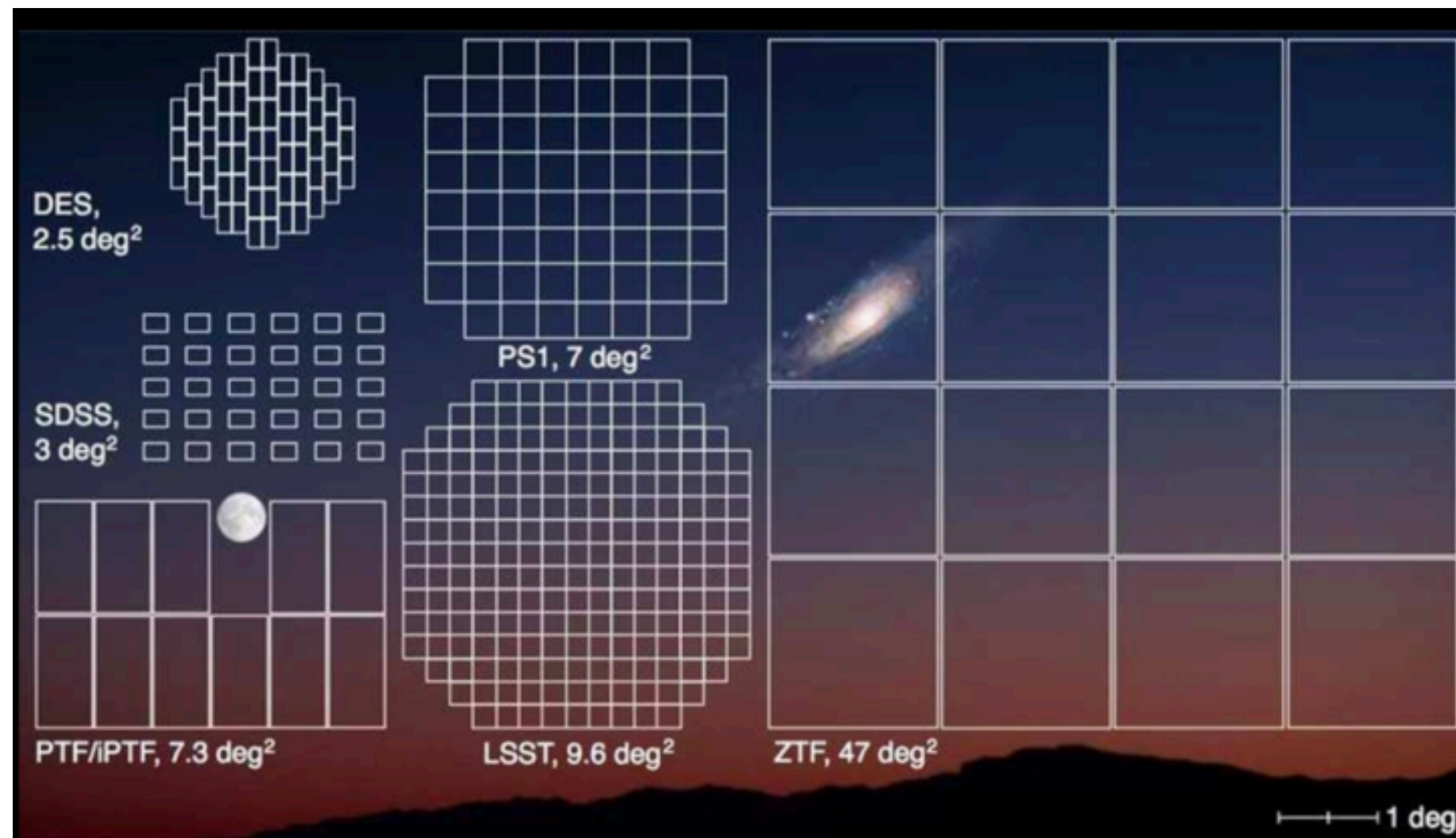
PhD goal

$$\mu + M = m_{obs} - \beta c + \alpha x_1 + p\gamma$$

ZTF



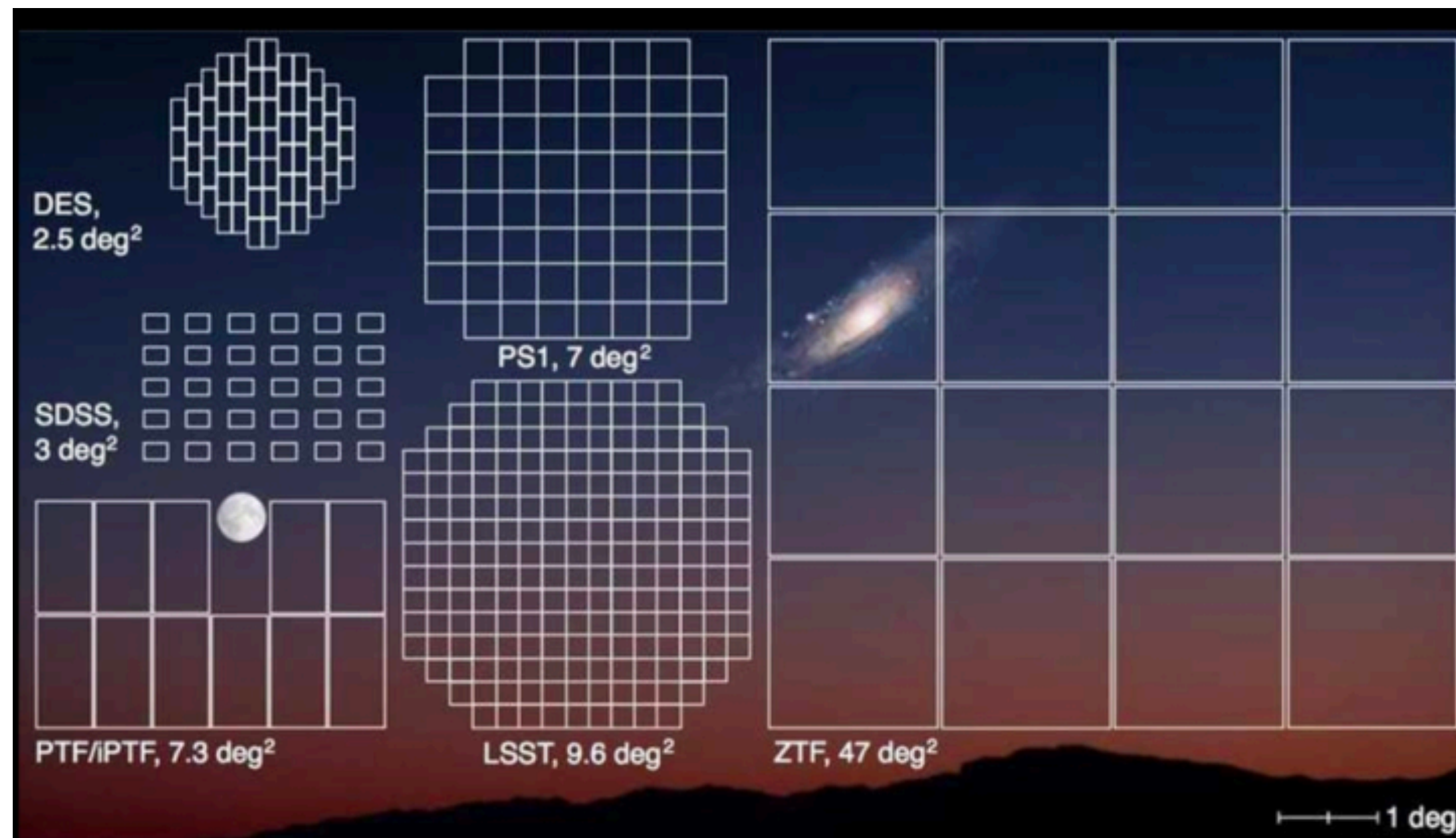
ZTF



Zwicky Transient Facility (P48)

- High FoV
- Short (30s) exposures
- 3 bands (g, r, i)
- Median depth in r band at ~ 20.4 mag ($z=0.1$)

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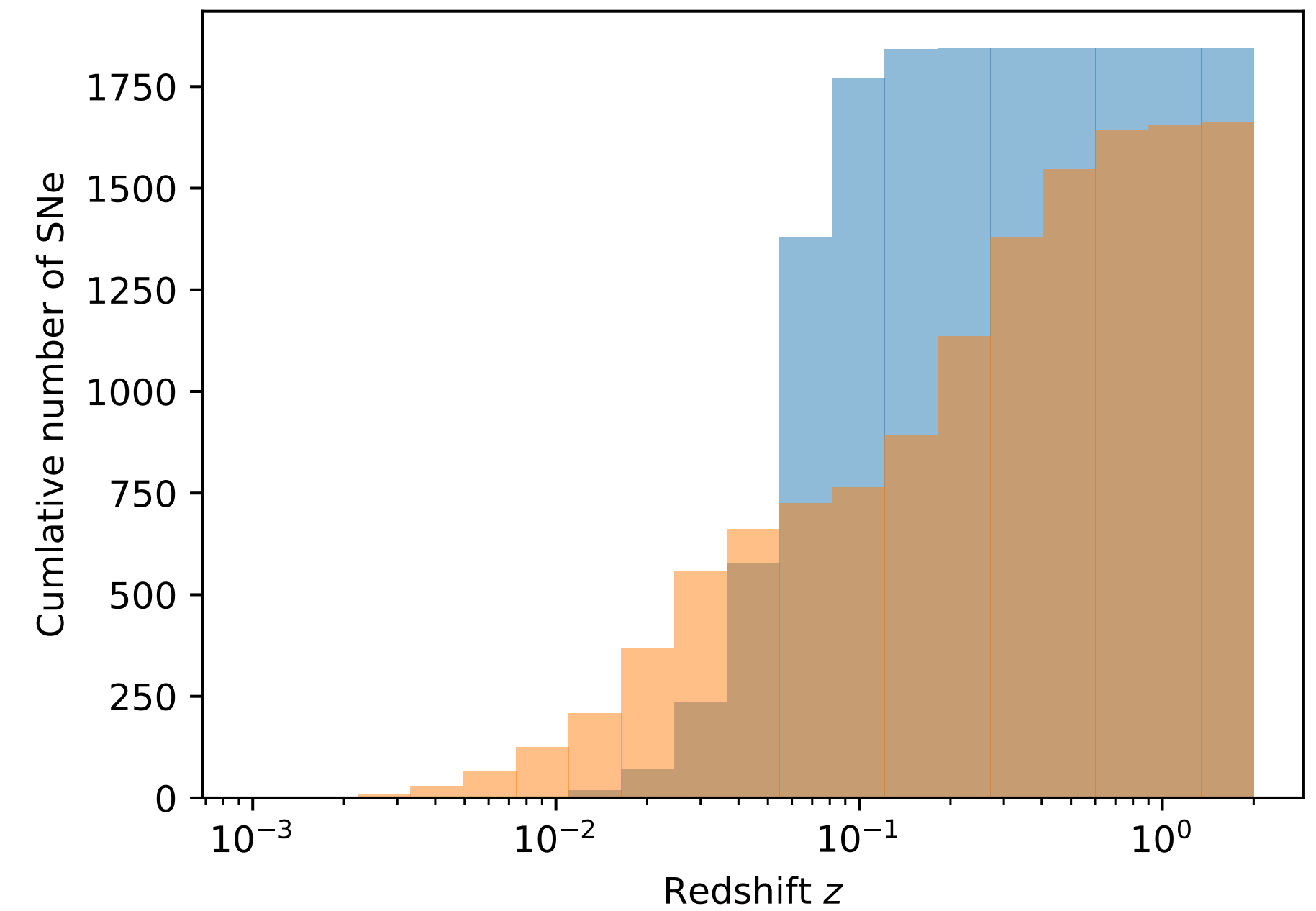
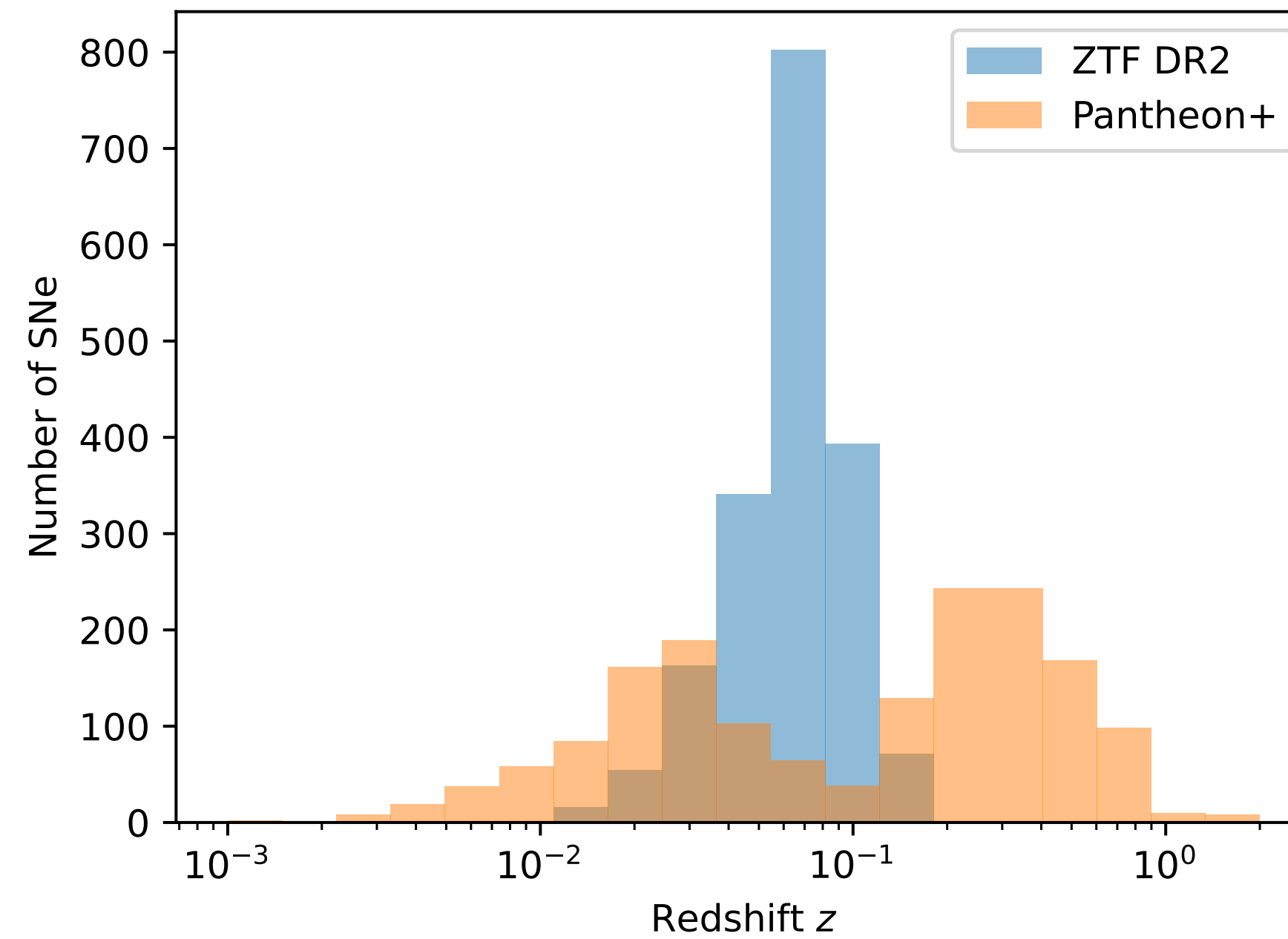
SEDmachine (P60)

- Low resolution ($\frac{\lambda}{\Delta\lambda} \sim 100$)
- ~ 1h exposure
- Limiting magnitude at ~ 19.5 mag

ZTF DR2

Numbers

Cosmological SNe Ia



➔ 3627 spectroscopically confirmed SNe Ia

➔ 2930 with a good light curve

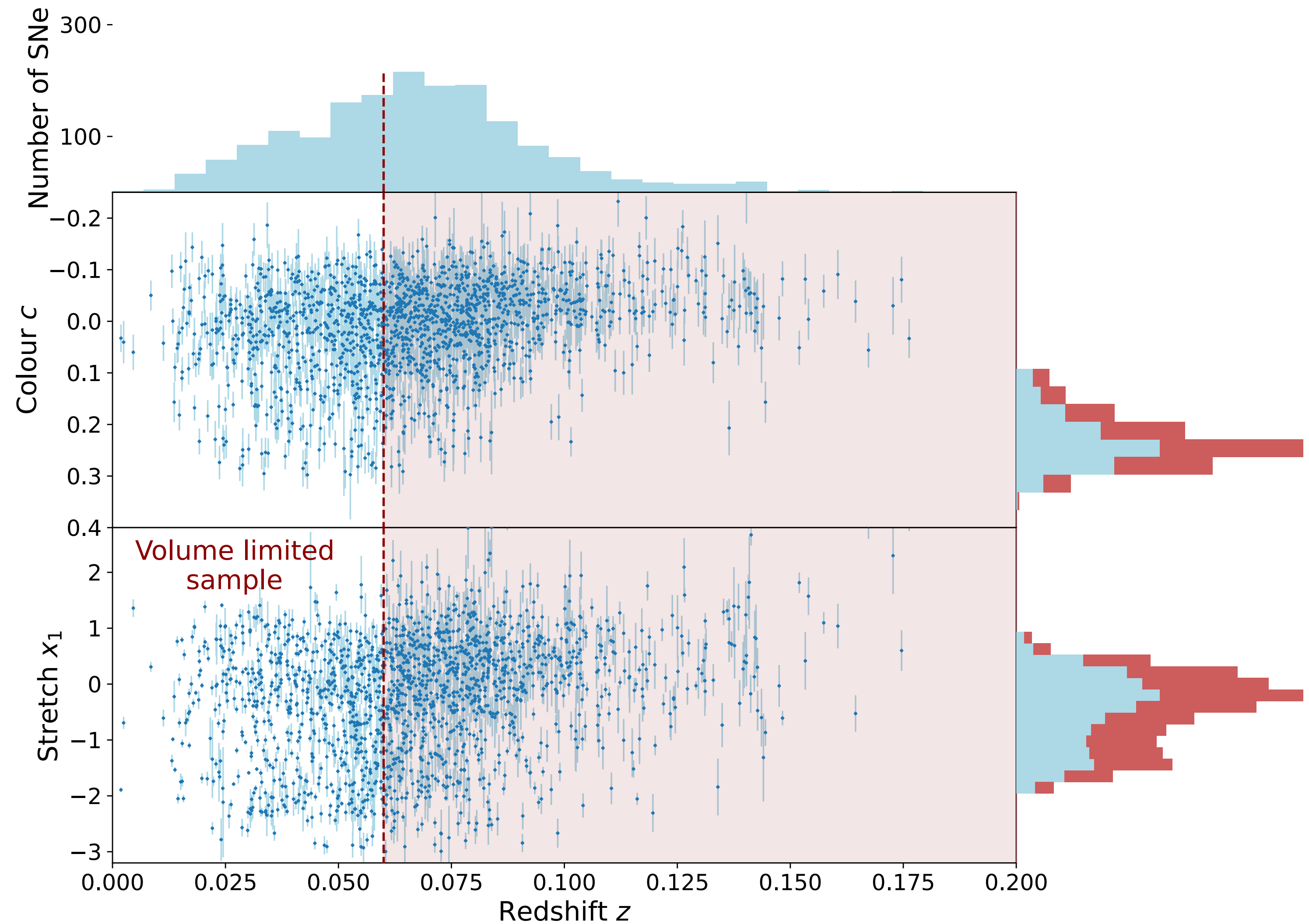
➔ 1843 cosmological Ias

ZTF DR2

Volume limited sample

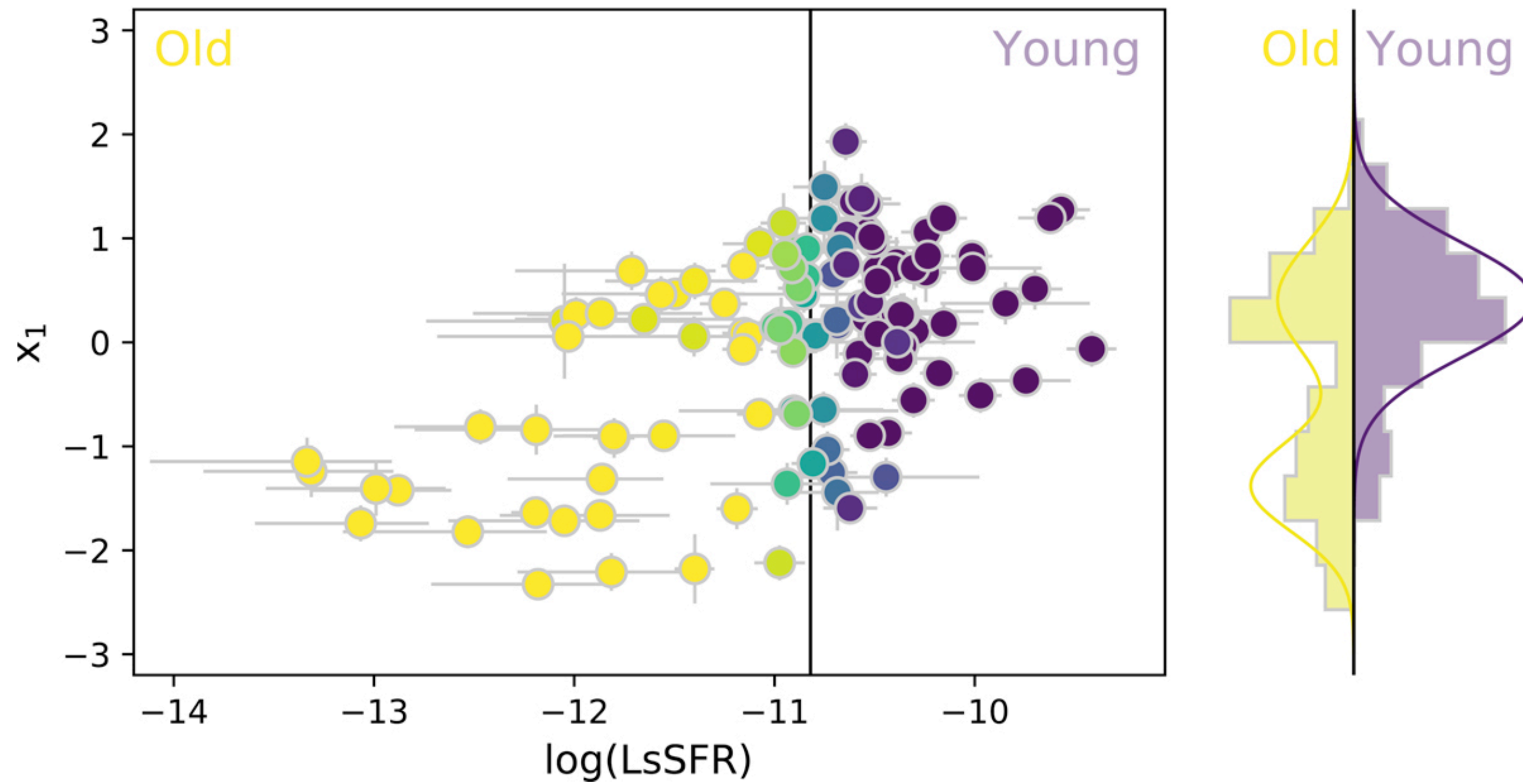
- Redshift cut: no selection effects
- Additional cuts:
 - (x_1, x_1^{err})
 - (c, c^{err})
 - t_0^{err}
 - Normal SNe Ias
 - SALT fit probability

➔ **670 SNe** in the final sample



Standardisation

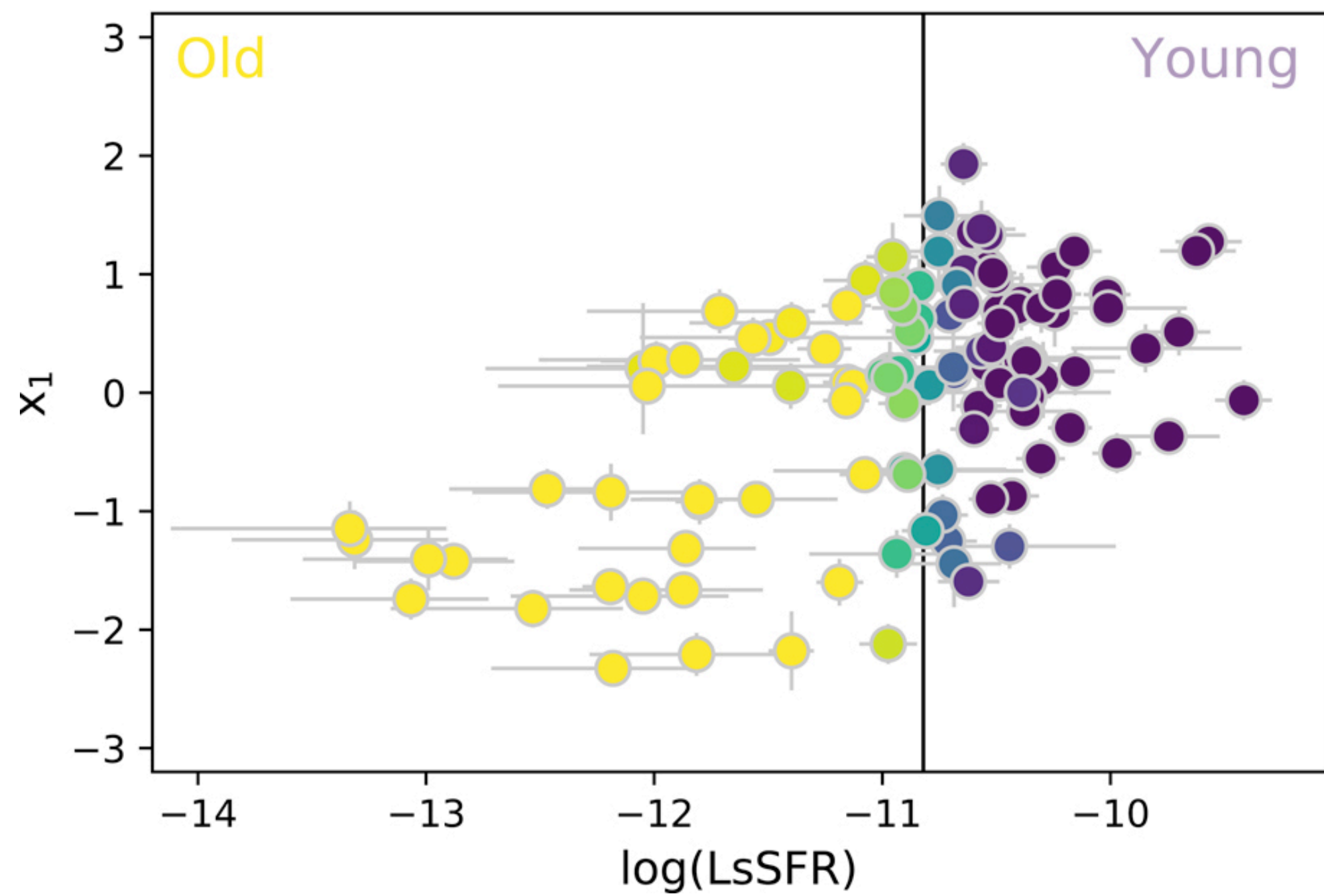
Stretch distribution



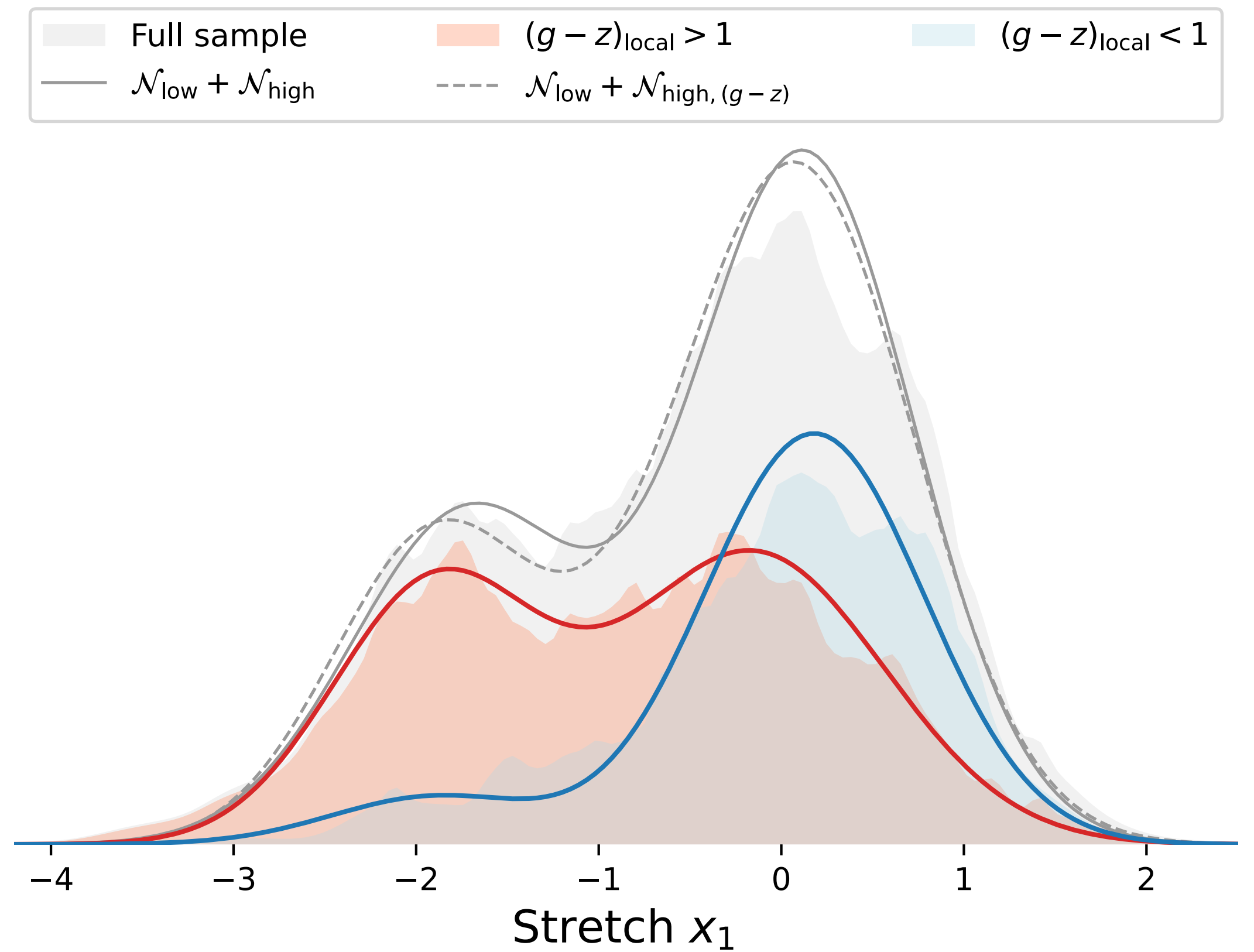
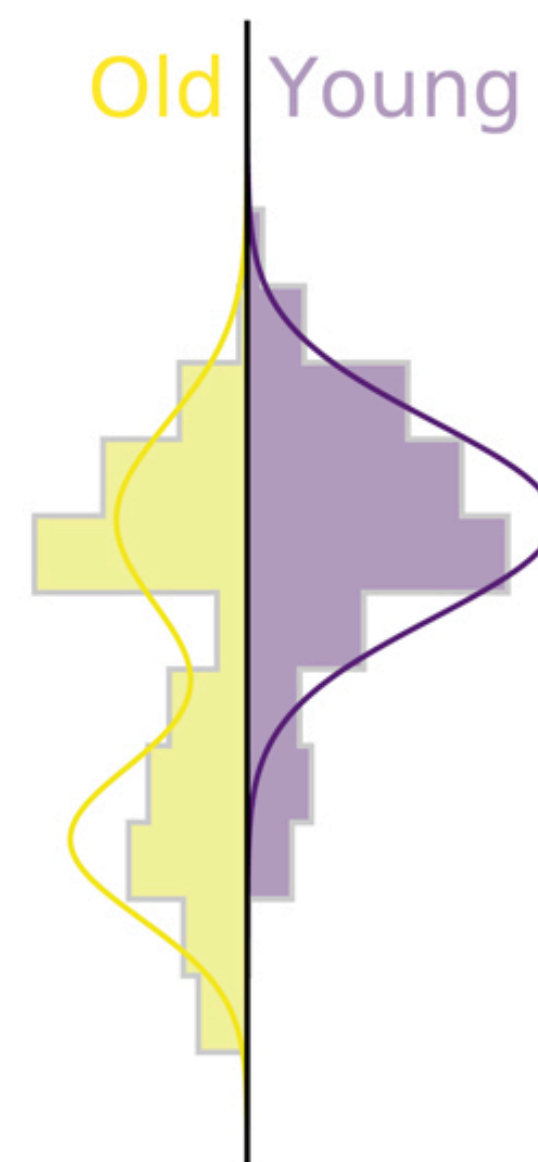
Nicolas et al (2021)
SNF - 114 SNe

Standardisation

Stretch distribution

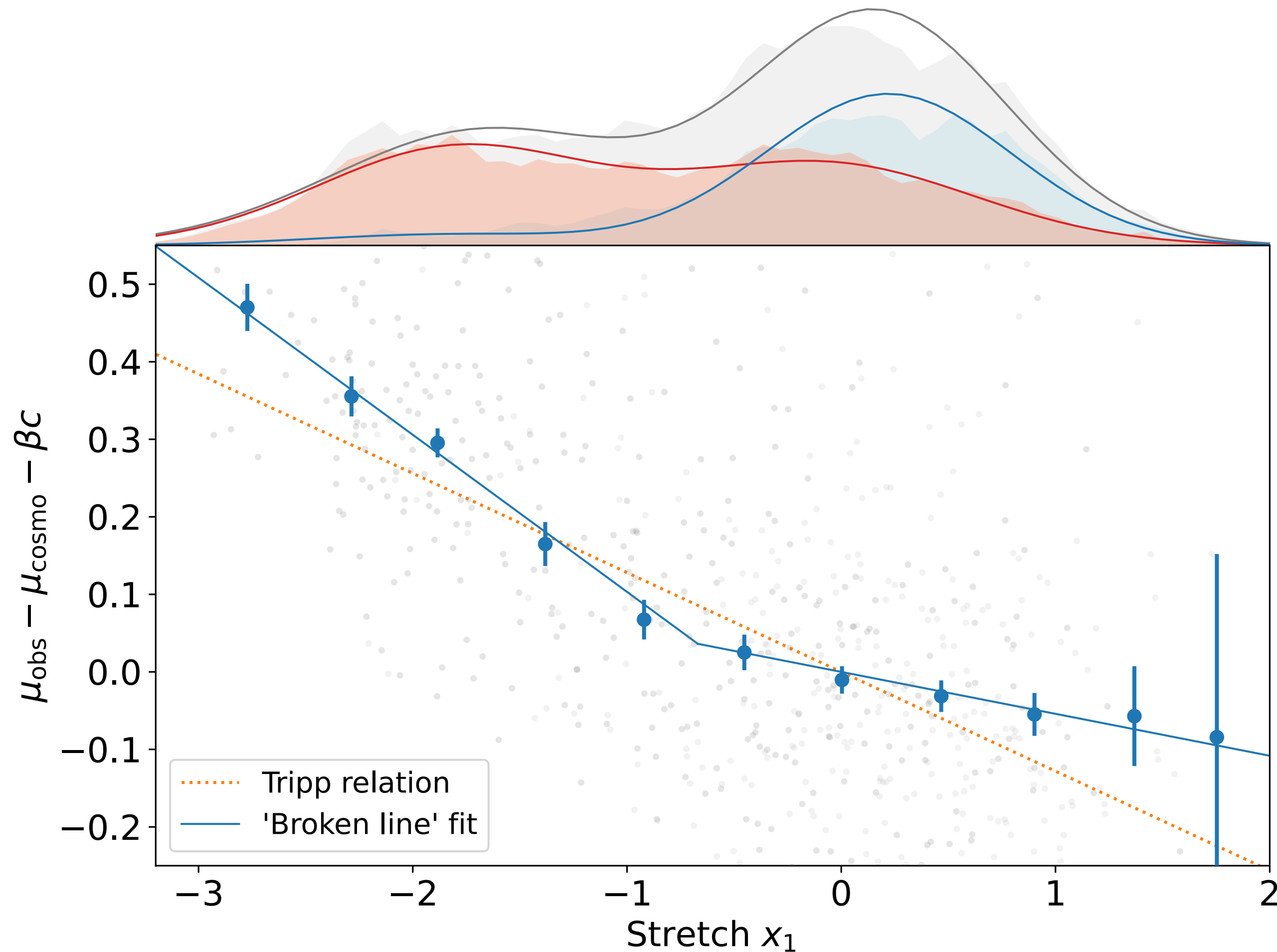


Nicolas et al (2021)
SNF - 114 SNe



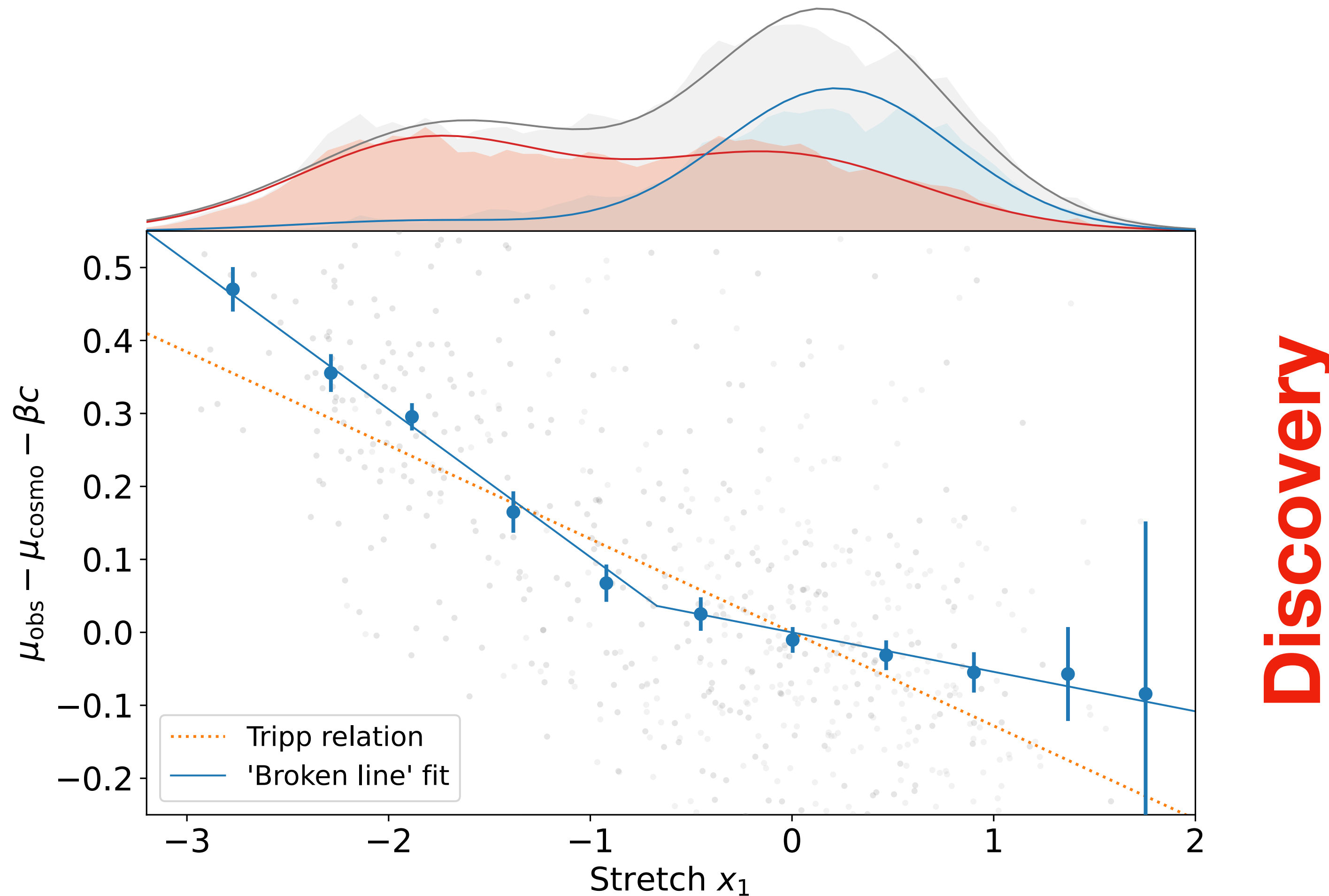
Standardisation

Non linearity of the stretch-residuals relation



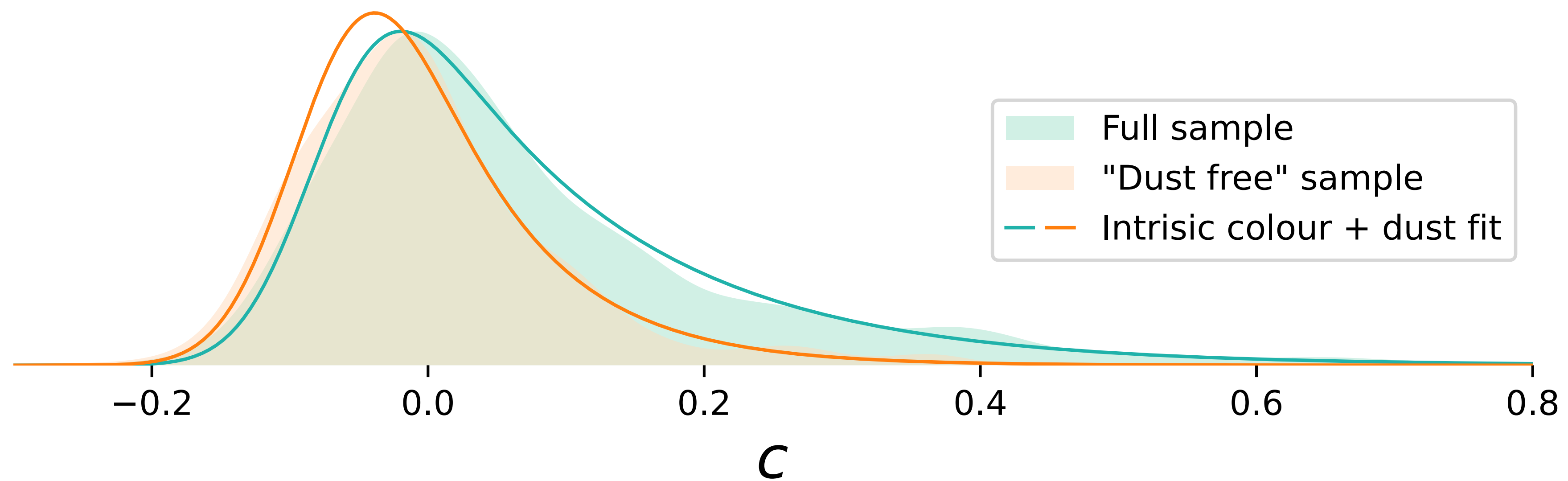
Standardisation

Non linearity of the stretch-residuals relation



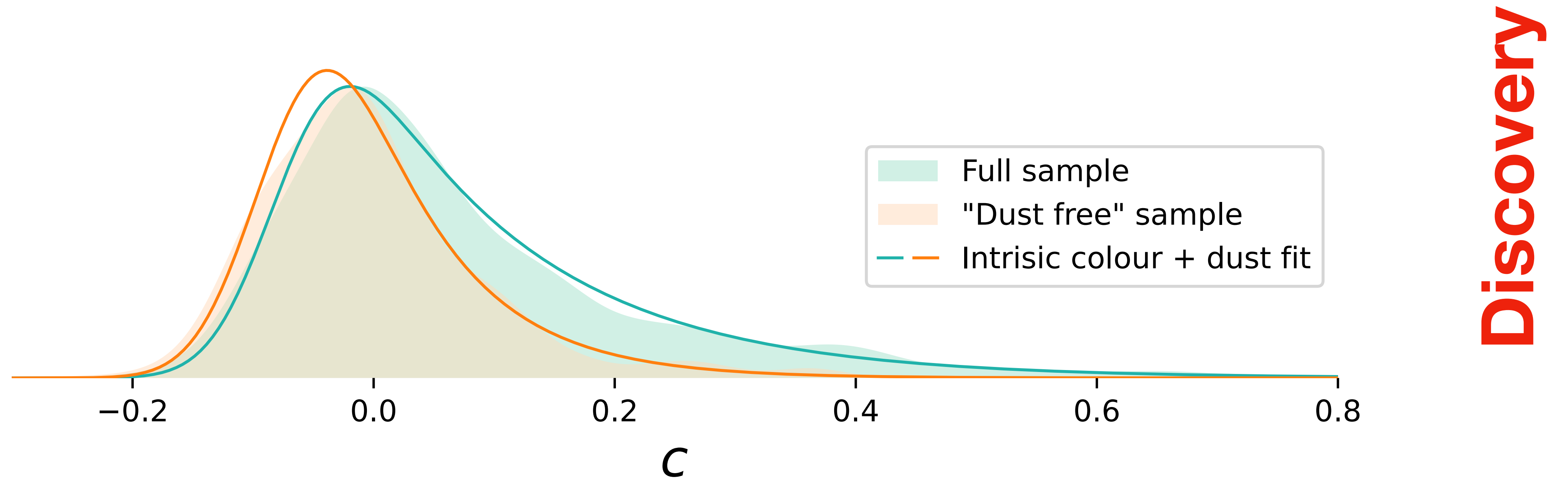
Standardisation

Colour distribution



Standardisation

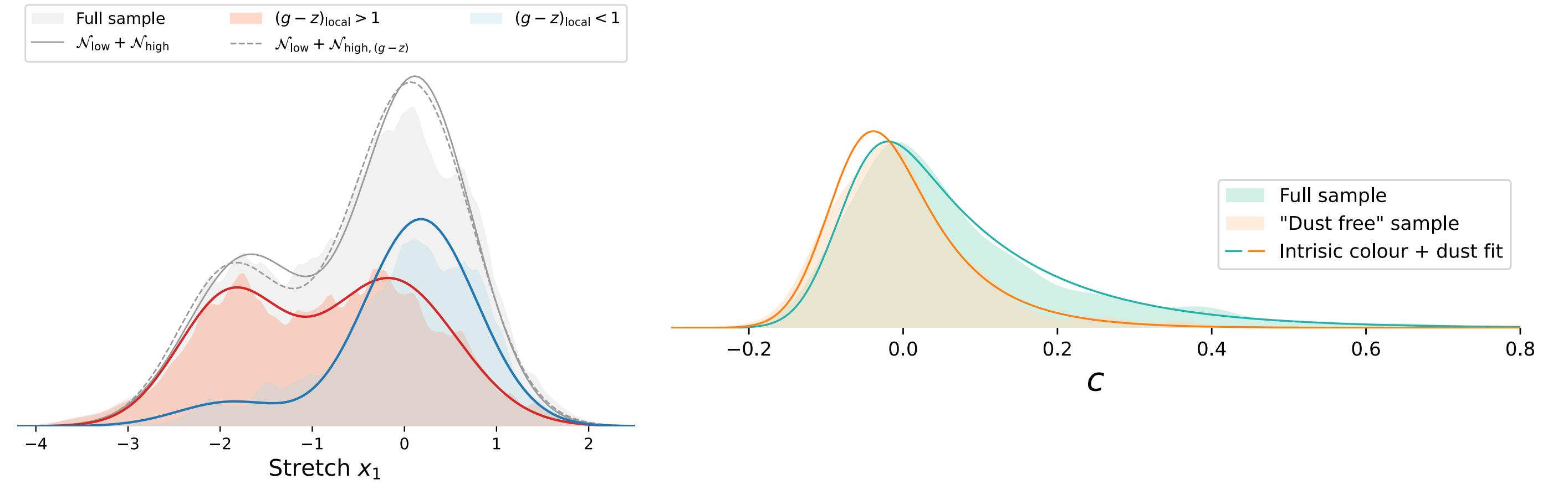
Colour distribution



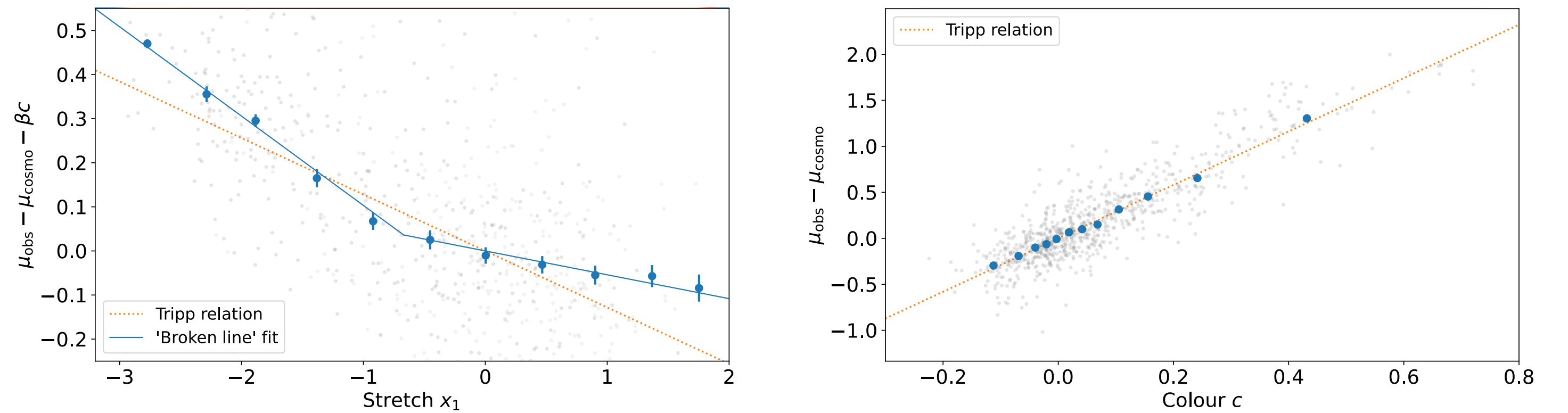
Conclusion

ZTF DR2

Supernovae physical properties

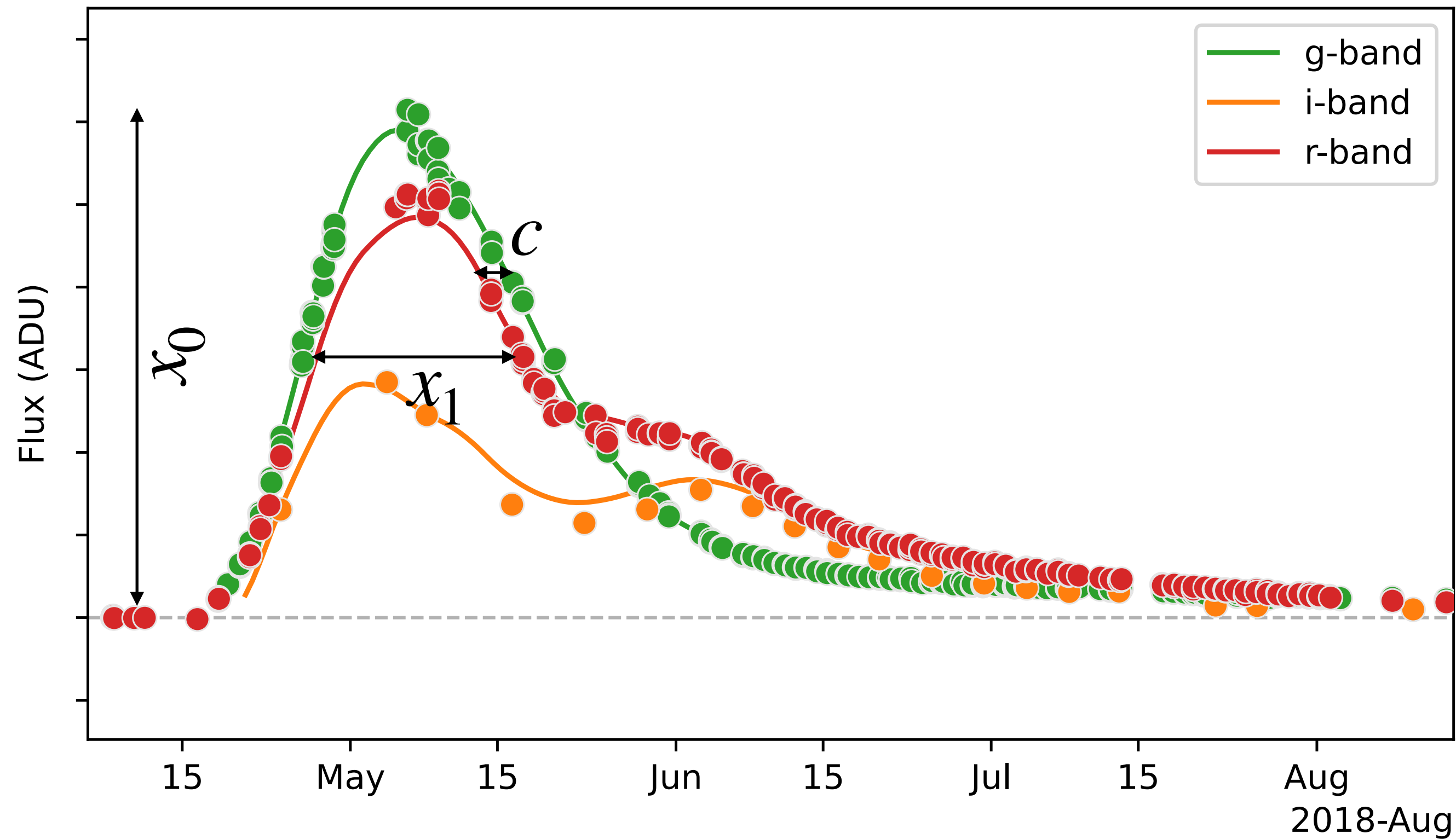


Standardisation linearity



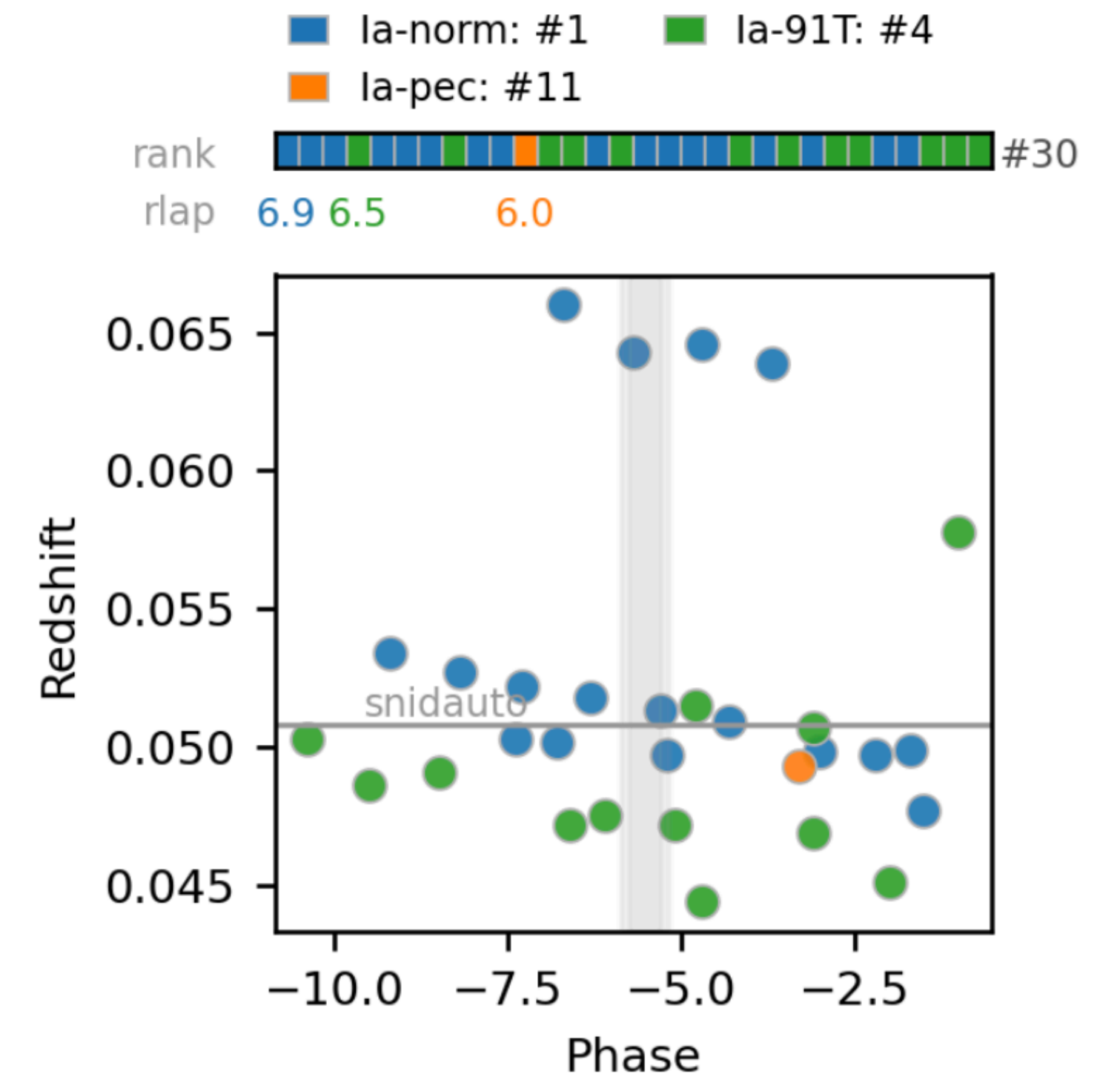
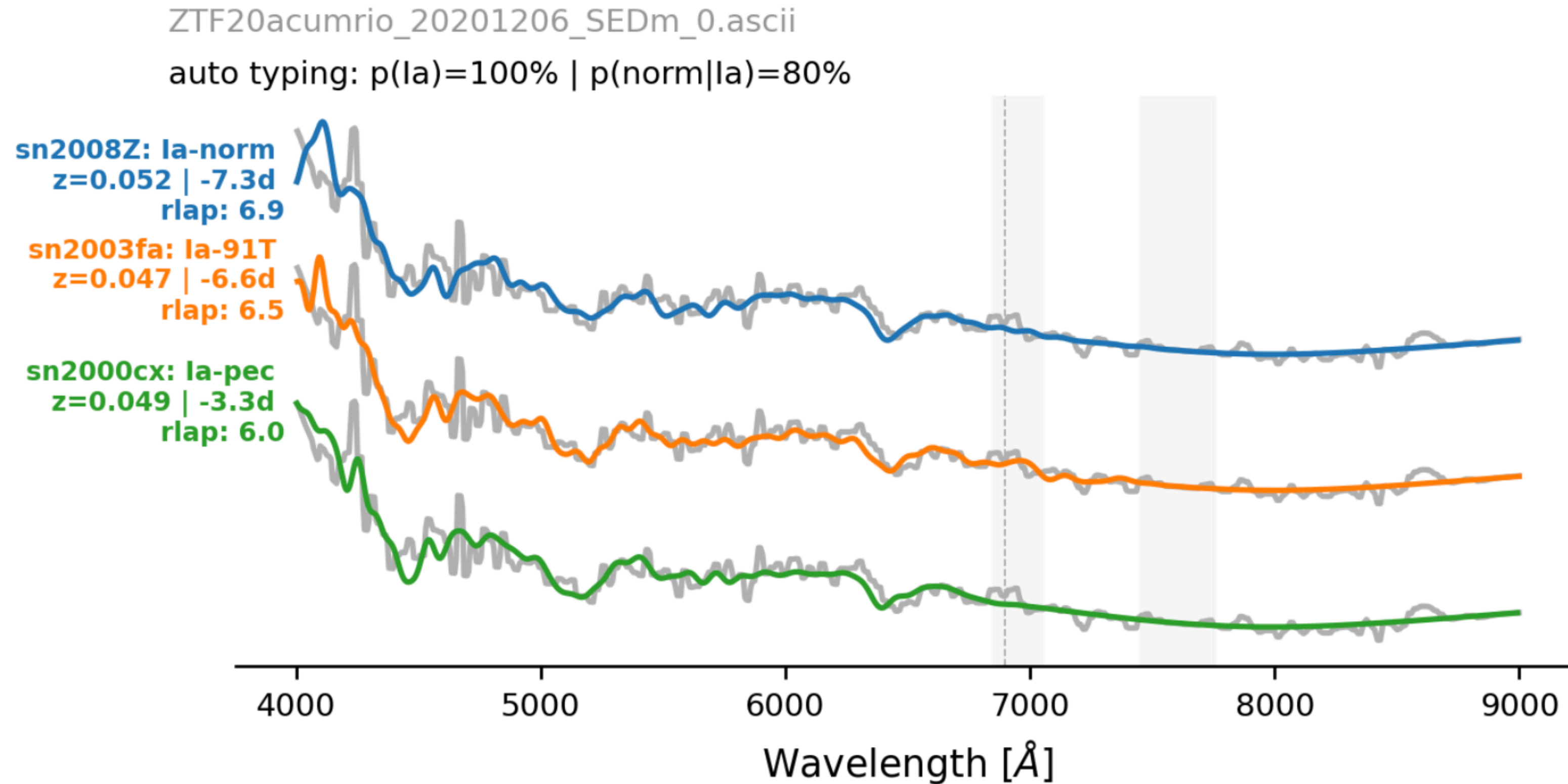
SALT2 (Guy et al 2007)

Functional form describing the flux: $F(SN, p, \lambda) = x_0 [M_0(p, \lambda) + x_1 M_1(p, \lambda)] \exp(c CL(\lambda))$



- Parameters relative to the SN
- Parameters relative to the observation

SNID (Blondin & Tonry 2007)



Credits: Typing App

Standardisation fit

Method: minimizing the log-likelihood $-2 \log(\mathcal{L})$ with the migrate method from the Minuit package

$$\begin{aligned}
 \mathcal{L} &= \prod_{i=1}^N \mathcal{N}(\mu_{\text{obs}}^i - \beta c^i + \alpha x_1^i, \mu_{\text{model}}^i + M, \sigma_{\text{tot}}^i{}^2) \\
 &= \prod_{i=1}^N \mathcal{N}(\text{res}^i - \beta c^i + \alpha x_1^i, M, \sigma_{\text{obs}}^i{}^2 + \sigma^2)
 \end{aligned}
 \quad \left\{ \begin{array}{l}
 V_{\text{obs}}^i = (1 \quad \alpha \quad \beta) \mathbb{C}^i \begin{pmatrix} 1 \\ \alpha \\ \beta \end{pmatrix} \\
 \mathbb{C}^i = \begin{pmatrix} \sigma_{\mu_{\text{obs}}}^i & \text{Cov}(\mu_{\text{obs}}^i, c^i) & \text{Cov}(\mu_{\text{obs}}^i, x_1^i) \\ \text{Cov}(c^i, \mu_{\text{obs}}^i) & \sigma_c^i & \text{Cov}(c^i, x_1^i) \\ \text{Cov}(x_1^i, \mu_{\text{obs}}^i) & \text{Cov}(x_1^i, c^i) & \sigma_{x_1}^i \end{pmatrix}
 \end{array} \right.$$